

icipe PERIODIC EXTERNAL REVIEW (IPER) (2018 – 2022)



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***icipe* PERIODIC EXTERNAL REVIEW (IPER) (2018 – 2022)**

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November 2023

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Acronyms and abbreviations

AAT	Animal African Trypanosomiasis
ACE	African Centre of Excellence
ACIAR	Australia Centre for International Agricultural Research
ACTS	African Centre for Technological Studies
AgriDI	Agri-based Digital Innovation
AHU	African Host University (of RSIF)
AHT	Animal Health Theme
ARPPIS	African Regional Postgraduate Programme in Insect Science
ARSO	African Organization for Standardization
BSF	Black Soldier Fly
CABI	Centre for Agriculture and Biosciences International
CBID	Capacity Building and Institutional Development
CBIS	Capacity Building and Integrated Sciences
CGIAR	The Consortium of International Agricultural Research Centres
DAAD	German Academic Exchange Programme
DFA	Director of Finance and Administration (of <i>icipe</i>)
DG	Director General (of <i>icipe</i>)
DMMG	Data Management, Modelling and Geo-Information (Unit)
DRIP	Dissertation Research Internship Programme
DRP	Director of Research and Partnerships (of <i>icipe</i>)
ERP	Enterprise Resource Planning
FAO	Food and Agriculture Organisation
FARA	Forum for Agriculture Research in Africa
GC	Governing Council
GFAR	Global Forum for Agricultural Research and Innovation
HHT	Human Health Theme
<i>icipe</i>	International Centre of Insect Physiology and Ecology
ICRAF	World Agroforestry Centre
IITA	International Institute for Tropical Agriculture
ILRI	International Livestock Research Institute
INSEFF	Insects for Food, Feed and Other Uses
IPER	<i>icipe</i> Periodic External Review
IPI	International Partner Institute (of RSIF)
IPM	Integrated Pest Management
<i>i</i>TOC	<i>icipe</i> Thomas Odhiambo Campus
JICA	Japan International Cooperation Agency
KEMRI	Kenya Medical Research Institute
MOYESH	MOre Young Entrepreneurs in Silk and Honey
NARs	National Agricultural Research Systems

NORAD	Norwegian Agency for Development Cooperation
NTD	Neglected Tropical Disease
OACPS	Organization of African, Caribbean and Pacific States,
PAR	Participatory Action Research
PASET	Partnership in Skills in Applied Sciences, Engineering and Technology
PPT	Push-Pull Technology
RBM	Results Based Management
RCU	Regional Coordination Unit (of RSIF)
R&D	Research and Development
R4D	Research for Development
ROI	Return on Investment
RSIF	Regional Scholarship and Innovation Fund
RT	Review Team
SDC	Swiss Agency for Development and Cooperation
SGI	Sponsoring Group of <i>icipe</i>
Sida	Swedish International Development Cooperation Agency
SME	Small and Medium-Size Enterprise
SSA	Sub-Saharan Africa
SSIAU	Social Sciences and Impact Assessment Unit
TEA	Techno-Economic Analysis
TRC	Tsetse Repellent Collar
TTU	Technology Transfer Unit
UNEP	United Nations Environment Programme
VIPP	Vegetable Integrated Push-Pull
V&S	Vision and Strategy (document)
WHO	World Health Organisation
WOAH	World Organisation for Animal Health
YESH	Young Entrepreneurs in Silk and Honey

EXECUTIVE SUMMARY

The International Centre of Insect Physiology and Ecology (*icipe*), an inter-governmental, not-for-profit research organisation, undergoes a periodic External Review (IPER) every five or six years. This IPER covers the period 2018 – 2022. Its objectives are to establish the alignment of *icipe*'s research and development (R&D) activities to the institutional mandate; the extent to which the activities meet the development needs of the beneficiary constituencies; *icipe*'s success in operationalising its *Vision and Strategy (2021 – 2025)*; and the effectiveness and efficiency of the Centre's management.

The IPER exercise commenced with a review of documents compiled by *icipe*, followed by visits to, and interviews with *icipe* teams at the Centre's Duduville Campus headquarters in Nairobi, Kenya; country office in Addis Ababa, Ethiopia; the *icipe* Thomas Odhiambo campus (iTOC) in Mbita Point, western Kenya on the shores of Lake Victoria; and the Centre's field station in Muhaka, coastal Kenya. The review team also visited selected field and research projects, and held meetings with a sample of *icipe* donors, partners, collaborators and stakeholders.

The findings of the IPER indicate that during the review period, against the background of various global, regional and national shifts, *icipe* has made numerous advances in accordance with the four objectives listed above.

icipe's **institutional mandate** is to conduct pioneering insect science, and to research, develop and disseminate alternative and environmentally friendly pest and vector management strategies that are effective, selective, non-polluting, non-resistance inducing, and are affordable to resource-limited rural and urban communities. The Centre also supports the sustainable use and conservation of beneficial insects. *icipe*'s ultimate goal is to help alleviate poverty, ensure food security, better health and the overall well-being and resilience of people, while preserving the natural resource base.

Over the past five years, insect-related menaces have heightened in Africa, not least due to the arrival of several invasive species including the fall armyworm, *Spodoptera frugiperda*; the tomato leafminer, *Phthorimaea (Tuta) absoluta*; as well as a locust outbreak in eastern Africa, the worst in decades, which started in 2019. These new threats pile onto existing challenges, including a plethora of crop pests, for example stemborers and the parasitic *Striga* weed, fruit tree and vegetable pests, and human and animal disease-transmitting vectors. Among the latter are mosquitoes, sandflies, fleas, tsetse flies, biting flies and ticks. These hazards are compounded by escalating factors such as climate change, poor soils and variations in land use.

As a result of these and broader circumstances, the **needs of the *icipe* beneficiary communities** have shifted significantly. There are new urgencies to provide a fast-rising population with healthy, adequate, safe, nutritious food, while transforming the food system; tackle Africa's disproportionate burden of vector-borne diseases, through integrated thinking and action on health systems; improve livestock health and productivity, while addressing its polarised role in greenhouse emissions and environmental degradation; generate novel income and job opportunities, especially for women and the youth; and build cleaner, healthier and more resilient environments.

In response to these imperatives, *icipe* has capitalised on its 4Hs thematic approach: Human Health, Animal Health, Plant Health and Environmental Health. This is a visionary, holistic integrated research and development (R&D) framework that uses insects as a common thread for socio-economic transformation in Africa. The 4Hs Themes are complemented by several specialised research support units. As well, capacity building and institutional building is a cross-cutting programme, alongside the strengthening of research and innovation excellence in the Africa.

Moreover, the *icipe Vision and Strategy (2021 – 2025)* envisages various action points for the Centre, in accordance with the rising developmental imperatives. Selected thrusts of the document include: expansion of the Centre's research towards the One Health concept; improvement of the adoption of *icipe* technologies; fast-tracking of the commercialisation of the Centre's products; strengthening the capacity for social science assessments; establishing better surveillance, forecasting and early warning systems of invasive insect species and help to develop national and regional policies to reduce the risks of invasives; contributing to tackling insect biodiversity loss; advancing microbiome research to find strategic entry points to reduce disease transmission; promoting soil health research; and expanding *icipe*'s geographical reach.

This section briefly highlights *icipe*'s key R&D achievements, outcomes and impacts, as well as an overview of the Centre's management and administration, during the review period. The section also summarises the recommendations and suggestions of the IPER Panel. It is worth noting that the response by the *icipe* Management to the recommendations of this IPER (2018 – 2022) is provided in Annex 1; and for ease of reference, the response by the *icipe* Management to the recommendations of the IPER 2013 – 2017, is provided in Annex 2.

Key achievements, outcomes and impact

Human Health Theme: *icipe*'s ground-breaking discovery, in 2020, of a previously unknown mosquito-associated microbe (*Microsporidia MB*), which can block the transmission of *Plasmodium*, the malaria parasite, from the mosquitoes to people at high rates, provides the potential for a revolutionary malaria control tool. In addition, the Centre has generated knowledge for evidence-based decision making for integrated vector management (IVM), and the mitigation of the emerging threat of residual and outdoor malaria transmission; the One Health approach for neglected tropical diseases; and novel understanding of emerging and re-emerging vector-borne arboviruses (including those that are zoonotic and transboundary).

Animal Health Theme: *icipe* is supporting sustainable livestock keeping by boosting efficiency and upscaling of its arsenal of tsetse control tools (primarily the repellent collar technology); development of a novel bioacaricide (Mazao Tickoff) for tick control, and the first ever protocol for bioacaricides in Kenya; a new effective, easy to use diagnostic method for the deadly African animal trypanosomosis; and understanding of non-tsetse fly transmitted trypanosomosis, which, in particular, will help to increase the resilience of camels which are an important resource in arid and semi-arid areas.

Plant Health Theme: *icipe* has built on the numerous benefits of its climate-smart push-pull to integrate the technology into a One Health package that incorporates vegetables and black soldier fly farming, leading to a resilient, circular and regenerative food system. In addition, the Centre has developed an agroecological, synergistic control package for fall armyworm management; upscaled its integrated pest management (IPM) packages for pests of fruit trees, thus helping to revive fruit cultivation and re-open the export of fruits (avocado and mango) from Africa; and mainstreamed soil health studies, including research on soil dwelling pests like nematodes, and on soil microbial communities.

Environmental Health Theme: The highly successful MOYESH project, being implemented in Ethiopia by *icipe*, the Mastercard Foundation and other partners, stands out as a model for holistic and inclusive job creation for youth in Africa. In addition, *icipe* is pioneering the domestication of stingless bees for income generation enterprises, pollination services, conservation and regeneration. Overall, the Centre is contribution to policy and regulatory frameworks for quality bee products, including organic honey certification and fair trade, while also promoting insect biodiversity protection.

Insects for Food, Feed and Other Uses (INSEFF) programme: As a pioneer in this emerging area, *icipe* is using a One Health framework to translate the reality of insects in the transformation of the current food system into a more sustainable and vibrant circular economy. Insects have a better ecological footprint and significantly lower greenhouse gas emissions. They provide an alternative, more affordable and nutritious source of food for people and livestock. They are also efficient in bio-converting waste into high-quality organic fertiliser, and they are the basis of pest control products and cooking and cosmetic oils. *icipe* has helped to create extensive awareness and capacity on insect-based entrepreneurship, and to develop national standards for the edible insect farming sector in Africa. It has partnerships with over 200 organisations in more than 60 countries around the world. The Centre has trained over 57,000 people, leading to the setting up of 1,400 enterprises. Insect farming requires minimal investments and is, therefore, ideal for women and youth. Indeed, *icipe* has earned global recognition, especially through the award of the Curt Bergfors Food Planet Prize in 2020.

Capacity Building and Institutional Development programme: The Centre's longstanding commitment to nurturing talent and leadership in insect science continues. Over the past five years, 265 new scholars joined the Centre's postgraduate programmes; 85 PhD and 105 MSc scholars completed their studies and graduated; and the Centre's scholars received close to 100 external awards.

Data Management, Modelling and Geo-Information: The *icipe* Data Research Management and Archiving Policy has been developed, and the Unit has aligned to it, the Centre's data infrastructure. A range of next-generation decision-making tools and models have been designed for the management of crop pests and disease vectors, and the sustainable use and conservation of beneficial insects. The Unit is also strengthening the data science skills of *icipe* teams, partners and various stakeholders in Africa and beyond.

Social Science and Impact Assessment: *icipe* now has a notably stronger capacity for critical analysis and insights on the dissemination, adoption, economic benefits, environmental impact and gender inclusiveness of the Centre's technologies and strategies.

Technology Transfer: The Centre has placed extensive effort in awareness creation, training, designing of numerous pathways for information dissemination and validation trials to upscale and extend the geographical reach of the Centre's technologies. For example, the number of adopters of the push-pull technology has more than doubled, and uptake has been extended to 14 new countries (making a total of 18 countries). Through private sector partnerships a range of *icipe* biopesticides have been commercialised. In total, 150 *icipe* public goods are being used in more than 40 countries in Africa.

BioInnovate Africa Programme: Managed by *icipe* since 2016, the Programme is one of the largest and most active initiatives devoted to the translation and commercialisation of innovative, biologically based research outputs in eastern Africa. BioInnovate has partnerships with over 1,000 scientists and innovators in 200 organisations in eight countries: Burundi, Ethiopia, Democratic Republic of the Congo (DRC), Kenya, Rwanda, South Sudan, Tanzania and Uganda. During 2018 – 2022, a total of 25 innovation projects were supported, with 17 products successfully tested, validated and launched in the market. Moreover, BioInnovate Africa helped to develop the eastern Africa Bioeconomy Strategy, the only such plan of its kind in Africa, and the second globally, after the European Union.

Regional Scholarship and Innovation Fund, a programme managed by *icipe* since 2018, has become one of the largest academic and research networks for nurturing the continent's talent and leadership in applied sciences, engineering and technology, which are priority areas of socioeconomic transformation. As of 2022, a total of 291 RSIF PhD scholarships have been awarded; and 8 out of 15 cohort 1 scholars have completed their studies. Currently, 37 percent (104 scholars) of the 278 active RSIF scholars are women. RSIF scholars had published a total of 144 peer reviewed papers and grantees had published 22 papers. Overall, RSIF funding has resulted in the publication of 166 research papers in international refereed journals as of 31 July 2023. Additionally, a total of 32 research and innovation grants have been awarded; and through a special agreement, 12 research and innovation grants have been provided to faculty and researchers in Mozambique. Several innovations have been developed, including Internet of Things devices, a solar heat pump drier for fruits and vegetables, biopesticides for yam fungi, and two patents in oil and gas.

Resource mobilisation

There has been a significant increase in project funding from donors during the review period, and *icipe* has welcomed 39 new donors. But there has also been a noticeable decline in core funding, a trend that started in the previous review period. However, efforts initiated during the current review period to overcome this downward trend in core funding have produced results in 2023, with several donors from Australia, Germany and Norway having pledged core funding. Attempts at implementing cost recovery in projects to supplement core funding has had limited success. Another challenge facing the Centre has been the limited adoption of its technologies in rural areas in Kenya. The Centre has also experienced difficulties in recruiting well-qualified insect scientists.

We conclude by noting that *icipe*, over its past fifty-plus years of existence, has grown into a world-class research-for-development organisation. The Centre, which has been recognised globally by international organisations and governments, is well-endowed with world-class laboratories, equipment and an outstanding research team, resulting in research of the highest level. It is important to note that this review period fell within the COVID-19 pandemic, which affected productivity at a global scale across all organisations. We commend *icipe* for resilience within the “business as an unusual” scenario. Further, this review period saw emerging crises, for example the war in Ukraine, which had an impact on donor funding. Much of the credit goes to an experienced and talented senior management team, scientists of the highest calibre and rigorous internal control processes to ensure accountability across the organisation. But like any organisation that is dependent on donor funding, *icipe* has faced challenges and will invariably continue to do so in the decade ahead. Many of these obstacles are external, over which *icipe* has limited control. Others can be addressed by *icipe* as outlined in our recommendations and suggestions. We are conscious of the fact that an entirely new senior management team will soon take over the leadership of the Centre, but we are confident that the foundation of the organisation is solid and that the new team should be able to steer *icipe* to even greater heights.

Recommendations

We acknowledge that there has been considerable expansion of the donor base; this laudable effort needs to continue with emphasis on maintaining the base and ensuring that the organisational priorities and mandate continue to align with the shifting attitudes of various donor agencies and governments; (ii) the GC needs to continue to support and expand **the Sponsoring Group of *icipe* (SGI)** to especially consider the issue of core funding for *icipe*; and (iii) **more resources need to be provided to its Resource Mobilisation Unit** to enable it to access additional digital tools for searching the availability of research grants internationally.

To undertake a study, through its SSIAU and TTU, to **establish the causes hindering the adoption of *icipe*'s technologies in rural areas in Kenya**; to make more concerted efforts to engage County governments in Kenya in implementing projects in rural areas and to provide opportunities to relevant authorities to visit the technology sites to enable them to understand these technologies and appreciate their impact.

Using **Climate Change as a One Health paradigm**, to undertake research on the effect of Climate Change on insects, and how this holistically impacts Plant, Human, Animal and Environmental Health.

- a. To develop a strategy to **improve the utilization of the ITOC**, which should include making available facilities more accessible to NGOs and other institutions in the region, identifying and supporting more research projects that can be implemented by ITOC, improving the quality of health facilities through the creation of a partnership with the County government to encourage more scientists to work there, and giving greater publicity to ITOC in *icipe*'s publications.
- b. To **mainstream youth** and, eventually, to consider creating in its organogram a separate Youth Employment Unit that would service the 4-Health Themes.
- c. To **extend its MOYESH-type project to other African countries** with support from the Mastercard Foundation, which will open up possibilities for *icipe* to expand its activities to West Africa.
- d. To **develop a “White paper” on scaling commercial opportunities using icipe technologies** within the framework of the Bioinnovate including a dedicated “Business Development” team in light of the high global interest in biopesticides as well as alternative protein sources.
- e. To continue to aggressively **pursue research on microsporidia and malaria**, seeking support from international organisations such as WHO.

Suggestions

- a. The new senior management team, once in place, to **recruit a new DRP or, preferably, to adopt a more devolved governance system** with leadership shared among the Heads of the 4Hs.
- b. *icipe* and RSIF to **consider options to review the problem of brain drain and, if warranted, consider options to minimize this in the region by working with national agencies.**
- c. In order to extend its activities beyond East Africa, to **look out for projects that target West and Southern Africa**, possibly by extending MOYESH-type activities beyond Ethiopia and, once a country office has been set up, to **assist it to eventually operate semi-autonomously.**
- d. To consider, as part of its public service mission, **creating a permanent educational exhibit of insects (for example an “Insect Museum”)** at its Duduville Campus.

1. INTRODUCTION

Established in 1970, the International Centre of Insect Physiology and Ecology (*icipe*) is an intergovernmental, not-for-profit research organisation, with a mission of using insect sciences to alleviate poverty, ensure food security and improve health while protecting the environment. *icipe* is globally distinct, being the only research institute working primarily on insects and other arthropods, and the sole institution that combines food security, human health, animal health and environment health. The Centre is also remarkable in its devotion and success in nurturing Africa's talent and leadership to produce and use insect science; the strengthening of doctoral training, research and innovation in applied sciences, engineering and technology, and the creation of a bioeconomy in Africa. With a 600-strong staff, *icipe* is headquartered in Nairobi, Kenya, with its Thomas Odhiambo Campus (iTOC) located on the shores of Lake Victoria in western Kenya, and country offices in Ethiopia, Uganda and Benin. The Centre has operations in 41 African countries and over 300 partnerships with a diverse range of organisations including academic, research, public and private institutions, as well as United Nations agencies across the world.

1.1 Vision, Mission and Mandate

icipe's vision is to pioneer global science in entomology, to improve the well-being and resilience of people and the environment to the challenges of a changing world, through innovative and applied research, alongside deep exploratory study, impact assessment, evaluation, and sustainable capacity building.

icipe's mission is to help alleviate poverty, ensure food security and improve the overall health status of peoples of the tropics by developing and extending management tools and strategies for harmful and useful arthropods, while preserving the natural resource base through research and capacity building.

The *mandate* of *icipe* is to research and develop alternative and environmentally friendly pest and vector management strategies that are effective, selective, non-polluting, non-resistance inducing, and are affordable to resource-limited rural and urban communities.

1.2 Governance

The supreme governing body of *icipe* is the Governing Council (GC). The Director General (DG) is responsible to the GC for the management and operation of *icipe* and is assisted by the Director of Finance and Administration (DFA), and the Director of Research and Partnerships (DRP). The position of DRP, however, became vacant in 2022. Also, both the current DG and the DFA will be retiring at the end of 2023. The DG is also assisted by a Senior Management Committee (SMC) that includes the DFA, the Heads of the 4Hs Themes, the Head of the Capacity Building and Integrated Sciences, the Head of the Ethiopia Country Office and the Manager, Research Innovation Coordination Units (responsible for BioInnovate Africa and PASET-RSIF programmes).

1.3 R&D overview

For close to three decades, the *icipe* R&D activities have been delivered through the 4Hs thematic approach: Human Health, Animal Health, Plant Health and Environmental Health. Currently, the 4Hs Themes are complemented by six research support units: Behavioural and Chemical Ecology; Molecular Biology and Bioinformatics; Data Management, Modelling and Geo-Information; Biosystematics; Arthropod Pathology; and Animal Rearing and Quarantine. In addition, the Social Sciences and Impact Assessment Unit and Technology Transfer Unit assist in the dissemination, adoption and critical analysis aspects, such as the economic and environmental effects, and gender inclusiveness of *icipe* technologies and strategies. The Capacity Building and Institutional Building programme crosscuts all activities. Also, *icipe* currently manages the BioInnovate Africa Programme, one of the largest and most active regional biosciences research and innovation-driven platforms in the continent. In 2018, *icipe* was competitively selected as the regional coordination unit of the Regional Scholarship and Innovation Fund (RSIF), a flagship project of the Partnership for Skills in Applied Sciences, Engineering and Technology (PASET) programme, an initiative established in 2013 by African governments with facilitation by the World Bank. (See *icipe* Organisational Structure in Annex 3).

The *icipe* 4Hs thematic approach is a visionary, holistic integrated framework that uses insects as a common thread for socio-economic transformation in Africa. Insects are intricately interlinked with our lives. As the most diverse and abundant form of life on Earth, insects are a paradoxical resource that harbours a myriad of benefits and numerous challenges. They create the biological foundation for all land-based ecosystems, provide pollination services and waste recycling; serve as an alternative, more affordable and nutritious source of food for people and animals, and as a basis of premium products that have diverse uses in the energy, industrial, pharmaceutical, food and crop protection sectors. In addition to honey, bees also provide wax, propolis and royal jelly, while silk from silkworms is one of the most coveted fibres in the world. Some insects control other harmful insects by parasitizing or preying on them. Above all, insects have a better ecological footprint and significantly lower greenhouse gas emissions. Of all the insects in the world, only 1 per cent are pests. Still, their damage is huge. For example, mosquitoes transmit the parasites of malaria, one of the world's deadliest diseases. Mosquitoes also transmit pathogens of other devastating ailments like dengue fever, Rift Valley fever and yellow fever. Tsetse flies, biting flies, sandflies, ticks and fleas, among other arthropods, are all disease vectors in people and animals. Indeed, the list of arthropod-borne viral (arboviral) diseases and their impact is extensive,

and most so-termed neglected tropical diseases are transmitted by insects. In crops, a plethora of indigenous and invasive pests pose challenges for food production and nutritional security. In Africa, where agriculture is by far the single most important economic activity, the impact of insects is significant.

While each of the *icipe* 4Hs Themes has a seemingly explicit and distinct mandate, their activities and impact is remarkably extensive. The Human Health Theme aims to generate knowledge and develop sustainable tools and strategies that control disease vectors, break the cycle of transmission, and which can be integrated into other disease management efforts. The goal of the Animal Health Theme is to create effective solutions to manage disease vectors and pathogens, to improve the health, productivity and sustainable livestock farming in Africa. The Plant Health Theme tackles native and invasive, below- and above- ground, pre- and postharvest pests, under changing climate and habitats. The Environmental Health Theme focuses on broadening knowledge on arthropods, their diversity and role in ecosystems, to contribute to conservation and sustainable use of biodiversity and their ecosystem services. In collaboration with the research support units, the Themes undertake multidisciplinary scientific research, generating world-class knowledge on aspects such as: vector-borne diseases, vector ecology and behaviour, vector-pathogen-host interactions; plant-insect-soil interactions; bee health and modern beekeeping, as well as the complex interrelationships between arthropod biodiversity, landscape and climate changes and ecosystem functions and services.

This knowledge is translated into nature-based, environmentally friendly, inclusive, innovative, accessible and affordable solutions, which are consolidated into integrated vector management (IVM) packages for the control of human and animal disease vectors; integrated pest management (IPM) packages for crop pests; and comprehensive approaches for sustainable insect-based enterprises. With the support of TTU and SSIAU, these packages are piloted and disseminated through engendered pathways, as well partnerships with numerous stakeholders and collaborators including research organisations, private sector actors, policy institutions, farmer groups and community-based organisations. This strategy transcends value chains, thus influencing policies, empowering communities and enhancing opportunities for income generation, and economic growth. All these efforts are pivoted by CBID programme, through the training of young scientists and partners, covering aspects from basic and strategic research, technology development and validation, and technology implementation and commercialisation.

In recent years, there has been a global resurgence towards the One Health concept. In 2021, the Food and Agricultural Organisation (FAO), the World Organisation for Animal Health (WOAH), the United Nations Environment Programme (UNEP) and the World Health Organisation (WHO) adopted the following operational definition, as recommended by an advisory panel: *“One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems”*. This unifying definition recognizes that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and inter-dependent.¹ Coincidentally, various recent and ongoing challenges, for example the COVID-19 pandemic, as well as the Antimicrobial Risk and Nutritional challenges facing the world, highlight the importance of the One Health paradigm, especially in a transboundary context.

Arguably, the far reaching and transformative impact of the 4Hs framework places *icipe* ahead of the curve in the global ambition towards One Health. The individual successes are being harnessed into explicit One Health initiatives. In addition, as recommended by the previous IPER and indicated in the Vision and Strategy 2021-2025 document, A One Health approach of the Centre has been an effective option to responding to developmental challenges.

Examples include:

- One Health approach for controlling tungiasis in Kenya – OX/BER (Oxford/Berlin) Research Partnership
- Combating Arthropod Pests for Better Health, Food and Resilience to Climate Change (CAP-Africa), funded by Norad
- Harnessing edible insects for One Health in Africa, supported by Curt Bergfors Foundation Food Planet Prize 2020
- Increasing diffusion and impact of the vegetable-integrated push-pull technology (VIPPT) in eastern Africa from a ‘One Health’ perspective
- Scaling regenerative black soldier fly farming innovations with vegetable push-pull cropping systems for One-Health in Rural Kenya, Rwanda and Uganda (IKEA Foundation)
- One Health Sustainability Partnership Between EU-AFRICA For Food Security (NESTLER)
- One Health approach for Food Nutrition Security and Sustainable Agriculture (FNSSA)
- Piloting novel, biorational, cattle-targeted interventions for sustainable control of arthropod vectors of malaria and other diseases of humans and livestock through multi-sectoral stakeholder engagement and community partnership

In 2016, the Swedish International Development Cooperation Agency (Sida) and *icipe* reached an agreement for the Centre to host and manage the Bioresources Innovations Network for Eastern Africa Development (BioInnovate Africa) Programme, Phase II (2016–2021). One of Africa’s largest regional science and innovation-driven initiatives,

¹ <https://www.who.int/news/item/01-12-2021-tripartite-and-unep-support-ohhlep-s-definition-of-one-health>

BioInnovate Africa was established in 2010 with support from Sida, its first phase running up to 2015. The Programme provides grants to enable scientists, researchers, innovators and entrepreneurs in eastern Africa (Burundi, Ethiopia, Kenya, Rwanda, Tanzania and Uganda), to work together to turn innovative ideas and technologies based on biological sciences into viable businesses. its emphasis being to develop and pilot economically viable biobased technologies and products; and to engage policymakers to evaluate relevant policy options that support bioscience innovations. The Regional Scholarship and Innovation Fund (Rsif – www.rsif-paset.org), was launched in 2015 as the flagship programme of the Partnership for Skills in Applied Sciences, Engineering and Technology (PASET), an initiative established in 2013 by African governments and partners. As a competitive grants scheme, the mission of Rsif is to strengthen the institutional capacity for quality and sustainable doctoral training, research and innovation in sub-Saharan Africa in five priority thematic areas identified by PASET as strategic economic sectors for growth and development in Africa. In 2018, *icipe* was appointed as the Regional Coordination Unit (RCU) of Rsif.

1.4 *icipe*@50

In November 2020, amid the COVID-19 pandemic, *icipe* celebrated its golden jubilee (50th anniversary), embodied in the slogan: ‘Insects for Life’ – a dual expression of the interlinkage between the 4Hs thematic approach, and the Centre’s unwavering commitment to its founding vision and mission. The hybrid event combined in-person and virtual participation, in observance of COVID-19 pandemic safety protocols. The centrepiece of the occasion was a recorded address by His Excellency, Hon. Uhuru Kenyatta, at the time the President of the Republic of Kenya, who also launched the *icipe* Vision and Strategy for 2021-2025. Other esteemed speakers included government representatives, and uplifting video messages from donors and collaborators. With the support of the Swiss Agency for Development and Cooperation (SDC), *icipe* published a special report entitled *Insects for Life: a brief history of icipe@50*. The official commemoration of the Centre’s golden jubilee was important: it was an occasion to contemplate the power of visionary thinking, of science and of movements of support and partnerships. *icipe*’s milestone was a much-needed beacon of hope, and a time for the Centre to re-dedicate itself to the mission of transforming livelihoods with insect science.

2. THE IPER

2.1 *icipe* Internal and External Reviews

icipe undergoes regular external and independent reviews to assess institutional performance and output and ensure that the quality and relevance of its activities comply with the Centre's mission. These include (i) research projects, which have specific mechanisms of review and planning, based on agreements with funding partners, and with close participation of the stakeholders (ii) the Sustainable Research Evaluation Systems (SRES) instituted by the Governing Council (GC), which assesses the scientific quality, translation of results into impact, human resources, partnerships, infrastructure, and capacity development of all scientific units to ensure that the scientific level of research remains at an internationally acceptable level and (iii) the *icipe* Periodic External Review (IPER) that broadly evaluates institutional mandate and programmatic activities to ensure they meet the development needs of *icipe*'s beneficiary constituency by reducing poverty, improving health, food security and their wellbeing. These reviews are not independent of each other and at the higher-level bullets (i) and (ii) can feed into bullet (iii). The IPER is commissioned by the Governing Council (GC) of *icipe* every five or six years as an instrument to review scientific programmes and the administrative and financial management of the Centre. Recent reviews include: IPER 2013 – 2017, undertaken in 2018; IPER 2008 – 2012, undertaken in 2013; and IPER 2002 – 2007, conducted in 2007. The IPER review teams are usually composed of three multi-disciplinary experts who are knowledgeable not only in their respective disciplines, but also in the global research agenda on agriculture, human health and the environment, and are also conversant with general developmental issues, institutional governance including management and resource mobilisation.

2.2 IPER 2018 – 2022

The objective of this IPER was to establish: alignment of *icipe*'s research and development (R&D) activities to the institutional mandate; extent to which the activities meet the development needs of the beneficiary constituencies; *icipe*'s success in operationalising its *Vision and Strategy 2021-2025*; and effectiveness and efficiency of the Centre's management.

The detailed Terms of Reference of the review are presented in Annex 5. The three reviewers, henceforth referred to as the Review Team (RT), were Prof. Goolam Mohamedbhai (Chair); Dr Felister Makini; and Dr Prem Warrior, whose profiles are provided in Annex 6.

The RT started its work by reviewing a 60-page document entitled 'Overview of *icipe*'s Achievements 2018 – 2022', which was specially prepared by *icipe* for the IPER. This document was accompanied by 19 Annexes, containing information on *icipe*'s R&D activities, its various support units, publications, awards, donors, partners, among others. These documents were uploaded on an IPER portal created by *icipe* for the RT. The portal was also populated with other relevant documents such as the *icipe Vision and Strategy 2021-2025* and *Vision and Strategy 2013-2020*, and the IPER 2013-2017 report, etc. The RT then visited *icipe*'s headquarters at Duduville, Nairobi where, over two days, they listened to presentations by the Director General (DG), the Heads of the 4Hs Themes, research support units, the Director of Finance and Administration (DFA) and managers under his responsibility. These presentations were immensely helpful to the RT in getting an overview of the organisation. All the PowerPoint presentations were uploaded to the IPER portal. The RT undertook visits to the *icipe* Ethiopia country office in Addis Ababa, the Thomas Odhiambo Campus (TOC), in Mbita Point on the shores of Lake Victoria, and Muhaka field station in coastal Kenya. The team also visited several *icipe* research field sites, met or communicated with a sample representative of *icipe* donors, partners, stakeholders and collaborators. All the visits were undertaken over the period 4-27 July 2023. Because of complicated individual travel schedules, in most cases the visits were undertaken by a single member of the RT. The RT also reviewed the minutes of most of the meetings of the GC and its Executive Board, and the Senior Management Committee (SMC). A virtual meeting was held with the Chair and Vice-Chair of the GC on 21 July 2023. The wrap-up meeting with the DG and the DFA was then held virtually on 31 July 2023, where the RT presented its preliminary findings and recommendations. During the writing of this report, the RT had regular virtual meetings. Through email exchanges, the RT obtained clarification from *icipe* management on several issues. A first draft of the report was submitted to *icipe* management on 19 September 2023 for factual verification and any views on the recommendations made. The finalised report was then presented to the GC. This report presents the findings of the RT. It denotes only an external point of view of the organisation at a specific point in time, based on what the RT has been exposed to. It was not possible to cover all aspects of this complex organisation in such a short time. Nevertheless, the RT hopes that its findings will be useful to *icipe*, and in particular, the new leadership team that will take the helm in January 2024, to address future challenges and seize new opportunities, as it continues on the ambitious journey of using insect science to overcome some of Africa's major development challenges.

3. RESPONSE TO RECOMMENDATIONS OF IPER (2013 – 2017)

3.1 Critical Recommendations

The previous IPER (2013 – 2017) made seven critical recommendations. In this section, we examine those recommendations, mention *icipe* management's initial response (*in italics*) in 2018 to each recommendation, and then briefly report on action taken by *icipe* over the current review period to address that recommendation.

One Health as an integrating paradigm

The review team recommended that, as a way of furthering the One Health paradigm, *icipe* should put in place a range of processes and practices and incentives that encourage projects to take a stronger systems approach in their design. *icipe management agreed but drew attention to the fact that funding One Health projects was a real challenge as most funders target specific R&D areas.*

As discussed in several sections of this report, *icipe* has made a special effort to leverage its 4Hs Thematic approach, and to ensure, whenever applicable, an interconnectivity and crosstalk among the Themes, essentially using the One Health concept, to achieve the outcomes for better lives among smallholder farmers in Africa. In 2022, a senior scientist was assigned the responsibility of interconnecting the Themes towards the One Health concept.

A draft One Health Strategy has been developed. Implementing the One Health paradigm is work in progress, as *icipe* and partners, especially donors continue to mutually align objectives accordingly.

Strategic capacity needs of an evolving *icipe*

The review team made several recommendations under this topic.

- a. The appointment of some critical high level vacant positions (in particular, Theme leaders) should be prioritised. *icipe management agreed and mentioned that efforts to fill the leadership of the Themes would be continued.*

Filling those leadership positions proved to be a challenge but most of the Health Theme leaders were subsequently appointed.

- b. One or two senior executive officers should be appointed to support Senior Management, which comprised the DG and two Directors, as the breadth of functions they carry out put extreme pressure on their time. *icipe management acknowledged that Senior Management comprising just three staff had led to a heavy workload on the team, a situation that was not sustainable.*

In 2022, the Director of Research and Partnerships moved to the position of Head of Capacity Building and Integrated Sciences, with the 4 Theme leaders now reporting directly to the DG (see Annex 3, Organisational Structure). The current Senior Management team, which is leaving *icipe* at the end of 2023, has decided to wait for the new incoming team to decide whether to fill that post. As discussed before the DG is also supported by a Senior Management Committee.

- c. *icipe* would benefit from stronger modelling capability, which would be particularly important in epidemiology and early warning systems. The Biostatistics Unit should also be strengthened. *icipe management agreed and mentioned there were plans to further strengthen this area as resources became available.*

In 2019, *icipe* established the Data Management, Modelling and Geo-Information (DMMG) Unit, one of its mandates being to establish next generation decision-making tools and models for the management of crop pests and disease vectors. The unit currently has 53 staff, students, and interns.

- d. The Social Sciences and Impact Assessment (SSIA) Unit should be expanded with new skills in sociology and/or anthropology. *icipe management's response was that appropriate staff were being recruited to fill the gaps.*

The staff have been recruited and are now in post. The Unit envisions further expertise in agribusiness and bioeconomic modelling.

Data management

The review team recommended that *icipe* should urgently implement a data management policy for a centralised archiving and backup of data sets, with clear protocols for those data sets to be accessible to other researchers; and resources to be assigned for implementing the policy. *icipe management's response was that policy development in this area would be prioritized.*

The DMMG Unit was subsequently set up in 2019, tasked with the establishment and enhancement of *icipe* data management and data sharing workflow.

Pathways to impact

There were two recommendations under this topic:

- a. *icipe* should build pathways to impact that include building the capacity of development partners. *icipe management agreed and mentioned that it had been involved in building the capacity of its development partners, giving several examples. icipe, however, recognised that instilling systemic and systematic change across the board of all value chain actors is a long-term process.*

icipe has, over this review period, engaged in capacity building at all levels; indeed, instilling change is a long-term process.

- b. *icipe* should place greater emphasis in developing innovative impact pathways, and that the Technology Transfer Unit (TTU), the BioInnovate Africa Programme and the SSIA Unit could help to overcome barriers to technology adoption. *icipe management agreed and quoted several effective and impactful examples of science translation and adoption.*

icipe has succeeded in achieving impact and overcoming barriers to adoption of several of its technologies. However, this has not been attained uniformly among all its beneficiaries and across all regions and countries where *icipe's* technologies have been introduced. For example, there has been remarkable impact in the MOYESH project involving the adoption of beekeeping and silk farming in Ethiopia. On the other hand, the impact of the push-pull technology in the Homa Bay County, western Kenya, to eradicate *Striga* weed appears to have been somewhat limited. Building pathways to impact, especially regarding poor rural communities, remains work-in-progress at *icipe*.

Operational modality to cover the African mandate area

The RT felt that *icipe* should extend its operations to other countries, creating regional offices in West and Southern Africa. It, however, recognised that this goal would require upfront core funding. *icipe management agreed and acknowledged that such extension of its activities would require additional core funding. The Centre also noted that its management of the RSIF programme might be a platform for such an extension.*

For example, as indicated in this report, *icipe* has established an office in Benin to implement the AgriDI project designed jointly by RSIF and BioInnovate. The Government of Benin is a contributor to RSIF which could help to create a synergy between AgriDI and RSIF.

Capacity building, institutional development and expanded outreach

Closely linked to the recommendation above, the RT suggested that *icipe* uses its Capacity Building and Institutional Development (CBID) programme to expand its outreach into West and Southern Africa by identifying centres of excellence in those regions. The Centre could direct 15-25% of its postgraduate intake each year to those selected centres, which eventually could become *icipe's* Partnering Institutes. *icipe management agreed and, again, felt that this recommendation could be implemented through RSIF activities.*

Ensure financial sustainability

The RT felt that any medium-term growth in funding in *icipe* will primarily come from restricted funding rather than core funding. Acknowledging that the Centre, was already doing so, the RT recommended that *icipe* should move towards cost recovery, and eventually to full cost accounting. *icipe management agreed, noting that it was moving towards full-costing of projects and improving cost recoveries. The Management believed that the main foundation for creating financial sustainability was through producing excellent scientific outputs and generating transformative technologies and products, as well as prudent and transparent financial management.*

There has been a significant increase in restricted funding over the current review period, and considerable progress has been achieved in increasing core funding. *icipe* continues to focus on increasing core funding. Cost recovery has been implemented and continues to help the budgeting process.

3.2 Other Recommendations

In addition to the above critical recommendations, the IPER (2013-2017) made several 'second-level' recommendations. We flag below those that we consider most pertinent, indicating action taken by *icipe* (*in italics*) over this review period.

- The RT made several recommendations regarding the composition of the *icipe* Governing Council and other related matters. These, however, required amending the Charter, and there is no provision for amendment in the Charter. *So, it was not possible to take any action.*
- The RT suggested that *icipe* should consider whether to continue publishing the *International Journal of Tropical Insect Science*, given the cost of housing the journal and its low impact factor. *The journal has now been transferred to Springer which publishes it in collaboration with the African Association of Insect Scientists.*
- The RT suggested within the Centre's vision of increasing the continent's PhD scientists in Africa, it would be prudent to ensure that there are teaching and research positions in public and private academic and research institutions to absorb them. *A tracer study conducted by icipe, on the ARPPIS PhD programme showed that about 75% of the Centre's alumni remain in research, development, academia and related fields in Africa. The suggestion made by the RT remains pertinent for icipe as the Centre has significantly increased its PhD student intake through the RSIF programme. The RSIF team is conscious of this concern and is taking appropriate steps.*
- The RT recommended that, over the next five years, *icipe* should consider a revised structure of its 4Hs Themes and research supporting Units, for example by placing some of the Units within the Themes. *This has not happened because the Units cut across all the Themes.*
- Noting that only one Theme Leader, on rotation basis, was attending the Senior Management Committee meetings, the review team recommended that all Theme Leaders should attend the meetings. *All appointed Theme Leaders now attend the Senior Management Committee meetings.*

4. ACHIEVEMENTS, OUTPUTS AND OUTCOMES (2018 – 2022)

Typical performance measures for research and development organisations include scientific peer-reviewed publications, patents, training and enhancing credentials of scientific and technical teams, continued ability to secure funds, creation of new partnerships, performance against key objectives, among others. Standard financial, administrative and human resources goals are additional vital elements, especially if they are governmental or non-profit organisations. In this section, we look at the performance of *icipe*'s various activities from the perspective of their achievements and outputs.

4.1. 4Hs Themes and Capacity Building

There have been numerous R&D accomplishments across all *icipe* 4Hs Themes over the period of this review, which are well-documented in the Centre's comprehensive Annual Reports and very informative quarterly e-bulletins. Here, we highlight selected outcomes that we consider to be the most significant, and which we either witnessed personally or which were presented to us.

4.1.1 Human Health Theme

- i. **Malaria control:** Between 2000 and 2014, globally, significant progress was made in tackling the disease, and the number of malaria-related deaths fell by an estimated 40%. However, from around 2016, there has been a noticeable plateau followed by a steady increase in malaria cases and deaths. According to the World Health Organization (WHO) *World Malaria Report* (2022), in 2021, globally, there were 247 million malaria cases (95% of them in Africa), resulting in 619,000 deaths (96% in Africa)². In fact, the international malaria community is wary of setbacks towards achievement of the goals and targets for malaria elimination (2016 – 2030) set by the WHO and the Roll Back Malaria Partnership to achieve malaria eradication by the year 2040. This is particularly due to growing resistance by mosquitoes to insecticides; changes in the composition of the malaria-transmitting *Anopheles* species and their behaviour, including a shift in resting and biting times and an emerging pattern where the insects now bite people outdoors. Indeed, outdoor biting by *Anopheles* mosquitoes has gained attention as one of the contributing factors to residual malaria transmission, the continued spread of malaria in a given area, despite full operational coverage with long-lasting insecticidal nets and indoor residual spray interventions. This scenario indicates that current mosquito and malaria control measures and their deployment levels are insufficient. Therefore, it is important to intensify existing strategies while developing novel tools.

Within this context, *icipe* has made the following contributions towards mosquito and malaria control and eradication:

- **Symbiont-based Control of malaria:** In 2020, *icipe* made the groundbreaking discovery of a microbe in *Anopheles* mosquitoes, which blocks transmission of *Plasmodium*, the malaria parasite, from the insects to people. The scientists found that the microbe, which they named *Microsporidia MB*, is passed on from female mosquitoes to their offspring at high rates and that it does not kill or cause obvious harm to the mosquito host. Further studies by the Centre showed that *Microsporidia MB* is also transmitted sexually between mosquitoes. This knowledge paved way to investigate a viable dissemination strategy to increase the spread of *Microsporidia MB* among mosquito populations, leading to a transformative malaria transmission blocking intervention. A range of advances have been made by *icipe* and partners, including: determination of the diversity of *Microsporidia MB* strains in *Anopheles* mosquito species in Kenya; the characteristics associated with high efficiency of the microbe in blocking the transmission of the malaria parasite; the effect of the genetic background of the host mosquitoes on *Microsporidia MB* infections; and the environmental factors that drive their fluctuations. A cost-effective and rapid method to detect *Microsporidia MB* has been developed, as well as tools to investigate, model and predict the microbe's levels in the field, and to provide foresight for malaria disease incidences. Semi-field test releases of mosquitoes containing the microbe have been conducted, as well as stakeholder analysis and mapping of the influences of *Microsporidia MB* use for malaria control in Kenya. The Centre and partners have also identified field locations for trials and are now planning next steps.
- **Knowledge for evidence-based decision making on complementary residual and outdoor malaria control interventions,** with insights on the biological and ecological adaptation of mosquitoes. The Centre's research confirms previous reports that the *Anopheles funestus* mosquito species is the main malaria vector, while also providing new knowledge that the species also transmits malaria outdoors. In addition, *icipe* research shows that mosquito species that have for long been considered secondary malaria vectors, for example *A. rufipes*, are gaining prominence in malaria transmission.
- **Integrated vector management (IVM) to sustain malaria control and achieve elimination.** Using the Centre's longstanding IVM experience, between 2017 and 2022, *icipe* implemented an initiative in southern Africa (Botswana,

² <https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2022>

Namibia, Mozambique, Eswatini, Zambia and Zimbabwe), to minimise the use of DDT, which commonly used for mosquito control in the region, and replace it with readily available, but not-widely used vector control tools like winter larviciding, bio-larviciding of mosquitoes and house screening. The initiative was supported, and highly commended by WHO-AFRO; and the Global Environment Facility (GEF) through the United Nations Environment Programme (UNEP). It provided recommendations for evidence-based decision-making on efficacy, cost-effectiveness and long-term feasibility of IVM approaches.

- In 2015, *icipe* built on its seminal study, published in 2015, which made the first global connection between *Parthenium hysterophorus* (a highly destructive invasive plant that is aptly known as famine weed), and mosquitoes. The findings showed that the weed is a preferred nectar source for *Anopheles* mosquitoes and it can sustain these insects by extending their lifespan even in the absence of a blood meal from people. In 2021, *icipe* published new evidence on the immense threat posed by the weed towards probable escalation of malaria incidents in East Africa. This recent study has a silver lining that certain chemical fragrances found in the roots of *Parthenium* could be used as a bait in combination with traps, to selectively capture pregnant female mosquitoes seeking egg laying sites.
- ii. **Neglected tropical diseases (NTDs):** A key achievement of *icipe* during this review period is the development of a One Health inter-disciplinary approach to reduce the burden of tungiasis, a highly neglected, debilitating disease, and a major public health challenge in many parts of Africa. The disease is caused by *Tunga penetrans*, a parasitic sand flea whose eggs, larvae and pupae develop in soils, including on unsealed earthen house floors. The adult fleas survive on their hosts, with the females penetrating the skin to breed causing inflammation, pain and itching, difficulty in undertaking routine functions such as walking, sleeping and working, and stigma. *icipe* researchers have developed an efficient and economical PCR-based kit to identify *T. penetrans* larvae, a major feat, as soil organic material is known to be rich in PCR inhibitors; a simple, affordable thermography technology to detect tungiasis-associated inflammation; a novel two-level classification of tungiasis severity; knowledge on the interactions between parasite and hosts; and disease burden including morbidity and severe inflammation.
- **One Health model:** In two sites, Kwale County along the Kenyan coast, and Busia County, western Kenya, *icipe* is implementing a One Health initiative, as a model for the simultaneous control of insect vectors of diseases that affect people and animals. The Centre is testing novel products and strategies, including an environmentally friendly biopesticide for a range of disease vectors. Cattle will be used as decoys and treated with the biopesticide, thus protecting the animals as well as people.
 - In combination, *icipe* is trialling a 'healthy home' concept. Housing is a key determinant of health with implications for physical and mental health. The home environment exposes occupants to disease vectors, bacteria, toxins and air pollution from cooking. By combining lessons from various *icipe* disease vector control initiatives, and community participation, the Centre has conceptualised and built healthy home demonstration sites. The healthy home features simple improvements using locally available materials to prevent people and animal diseases. It has smooth walls to prevent the breeding of bedbugs and other biting insects, screened eave gaps, windows and doors to stop mosquito entry, roofs that allow water harvesting, sealed floor to prevent parasitic and bacterial diseases such as tungiasis, kitchen with improved cooking stove using briquettes thus reducing respiratory related challenges while conserving forests, latrine and bathroom where the human waste is digested with bacteria and used as fertiliser for kitchen gardens to improve food and nutrition security, while the fruit trees planted on it improve the environment. In addition, the healthy home separates the sleeping areas of chickens and people, and other livestock kept in enclosed bomas with good animal husbandry. Such a healthy home has been built at the *icipe* Muhaka field station within a government health facility. It serves as a training hub for communities and school children. Muhaka is an average sized village of about 2,000 people and is ranked among the poorest villages in terms infrastructure and resource development in Kenya. An estimated 70% of its population lives below the poverty line. The total cost of a healthy home is about USD 500. The 'healthy home' concept has been received by stakeholders with great enthusiasm and it lays the foundation for similar interventions. The RT witnessed a member of the community who has adopted the healthy home and is reaping the benefits. It is expected that the cost of a health home will be lower should more villagers build the homes themselves without incurring the cost of labour and putting together the local building materials. There is great potential for the healthy home concept to address the existing key health constraints in the community. Young people have been trained to collect data and to act as champions of the innovation.
 - During the review period, *icipe* also expanded its long-standing research on *leishmaniasis*, an NTD whose pathogens are transmitted by sand flies, through a comprehensive approach to understanding the diseases expanding geographical distribution. Significantly, in 2022, *icipe* supported the Kenyan government to respond to a leishmaniasis outbreak in one county.
- iii. **Tackling the increasing threat of new and re-emerging viruses:** In recent years, some arboviral diseases, such as yellow fever, Rift Valley fever and dengue fever (which are transmitted by a variety of mosquito species) have re-emerged. *icipe* continues to produce extensive knowledge on factors such as vector abundance, vector-pathogen interactions, vector competency, transmission and disease risk. In addition, in 2022, the Centre supported the Kenya government to respond to a yellow fever outbreak in two counties in the country. *icipe* also detected a previously

unknown phlebovirus and designated it as Ntepes virus. Further, the Centre has implicated sand flies in the circulation of the virus, with evidence of human circulation. In addition, *icipe* made the first record of the Jingmen tick virus in Kenya, and in a reptilian host; and first report of Ngari virus in livestock hosts in Kenya. *icipe* also generated additional knowledge on zoonotic pathogens, especially their interaction between the pathogens, livestock and wildlife.

4.1.2 Animal Health Theme

- i. **Integrated tsetse fly management:** Over the years, *icipe* has developed an arsenal of tools to control tsetse flies, which transmit the deadly Animal African Trypanosomiasis (AAT), and are among the most important constraints to livestock development in Africa. In its early years, the Centre discovered compounds in waterbuck, a large antelope found in sub-Saharan Africa, which repel tsetse flies. A blend of these chemicals has been packaged in innovative dispensers which, when worn as collars around the neck of cattle, essentially make cattle unattractive to tsetse flies. The *icipe* Ngu trap is built on visual (shape and colour) and smell-based cues (for example, cow urine and acetone), that attract tsetse flies. In the previous periods, *icipe* piloted the tsetse repellent collars with communities around Shimba Hills, coastal Kenya. *icipe* also tested a ‘push – pull’ strategy, using the tsetse repellent collars to ‘push’ away tsetse flies from the animals, and attractants to ‘pull’ them to the NGU traps. Social economic studies showed that the tsetse repellent collars and odour-baited traps, used individually or in combination, had been highly impactful in various sites across Africa.

During this review period, *icipe* collaborated with private sector partners to scale-up the mass production and roll-out of the tsetse repellent collar technology, backed by a business plan for commercialisation, packaging and wider dissemination. *icipe* bolstered marketing and distribution of the technology through agreements with private sector partners; a cloud-based agrovet system known as LiMA developed and implemented through a partnership with mHealth Kenya Ltd; collaboration with community owned resource persons (CORPs) and local government; training of farmers, the Kenya Tsetse and Trypanosomiasis Eradication Council staff and other government agencies.

Although a household survey showed 63% of the farmers’ willingness to pay the tsetse repellent collars at the same cost they incur treating an animal for AAT, in reality, they have competing needs and are thus unable to purchase the repellent at about USD 2.12 every six weeks.

The Centre also extended the integrated tsetse and trypanosomosis management technologies to Borana zone, Ethiopia, with local partners, pastoralist and agro-pastoralist communities. *icipe* also continued studies to bolster the technologies. For example, the Centre discovered zebra odours that could increase the effectiveness of the tsetse management collars technology and NGU traps. The researchers also conducted modelling studies to update tsetse and animal trypanosomosis risk maps in East Africa.

- ii. **Non-tsetse transmitted trypanosomosis/camel health and resilience:** Using the experience and knowledge gained through the development of technologies for the control of tsetse flies, from 2015, *icipe* initiated new research for the control of camel disease vectors in arid and semi-arid lands of SSA. Specifically, the focus has been on surra, a parasitic disease of camels and other mammals caused by trypanosomes, transmitted by biting flies. The disease causes frequent abortions, loss of condition and vulnerability to other infections. No vector control technologies are available and there is poor diagnosis of the disease, as well as increasing resistance to drugs. *icipe* studies are producing *novel knowledge of surra vectors*, including *Stomoxys* and *Hippobosca* flies, with promising leads for their control.
- **Better diagnosis tools for animal diseases:** One of the main challenges in tackling diseases like African animal trypanosomosis is difficulties in diagnosis. Often, livestock keepers make speculative, symptom-based diagnosis, and a high proportion of infections are either undetected or misdiagnosed. Lack of treatment or wrong therapies lead to livestock deaths, and in the latter case, drug resistance. A recent breakthrough by *icipe* is the identification of compounds known as ionones in the urine of cows, whose production is specifically stimulated by trypanosome infections. Therefore, these compounds are predictive biomarkers of African animal trypanosomosis. Using the biomarkers, through a simple urine test, which can be administered even by livestock keepers, it is possible to confirm whether an animal has the disease. This knowledge has enabled the Centre to develop a non-invasive, rapid, affordable, accessible efficient and easy-to-use tool to diagnose the disease. The biomarker-based diagnosis can be translated into a ready-to-use, inclusive innovation. For example, it can be packaged into a dipstick that can be easily applied to a urine sample.
- iii. **Tick and tick-borne diseases:** ticks – small, blood-sucking arachnids — are external parasites that are among the most important disease vectors of livestock including goat, cattle, sheep and camel, with the latter being the most preferred host. They transmit more pathogenic agents than any other arthropods, and they are considered to have roles in the transmission of zoonotic and other emerging pathogens. The use of chemical acaricides remains the primary approach to the management of tick-borne diseases. However, ticks have developed resistance to most such products. In collaboration with Real IPM Biobest, a private sector company, *icipe* has developed a fungus-

based bioacaricide (Mazao Tickoff), as an alternative to chemical acaricides. Mazao Tickoff is specific to insects and it has no safety risk to people, animals and the environment. However, a stringent evaluation and conclusive evidence of the effectiveness of the acaricide are critical for its registration and scaling-up. For the first time in Africa, *icipe* and partners developed and published a randomised efficacy protocol for the testing and use of bioacaricides. The Centre used this protocol to conduct a large-scale efficacy trial of Mazao Tickoff along the Kenyan coast. The protocol is a reference point for bioacaricide registration in Kenya. An application for the registration Mazao Tickoff has been submitted to Kenya Veterinary Medicines Directorate.

4.1.3 Plant Health Theme

The Plant Health Theme extending to soil health has seen significant technological advances that have continued to attract the attention of the scientific world and donor community.

- i. The flagship project of the Plant Health Theme is the **push-pull technology**, which was developed by *icipe*, Rothamsted Research, UK, and partners in East Africa over two decades ago, originally targeting stemborer pests. It is an agroecological approach that exploits insect-plant, and insect-insect interactions. The technology involves intercropping cereal crops with plants, for example legumes of the *Desmodium* genus, which produce defence compounds that repel (push) stemborer moths away from the target food crop. In addition, a fodder grass, for instance *Brachiaria* or Napier (*Pennisetum purpureum*), is planted as a border crop, and it releases chemicals that attract (pull) and trap the stemborers. As a result, the cereal crop is protected from the pests, thus offering an elegant, economical and environmentally safe pest management tool. An additional benefit is ability of *Desmodium* to reduce the *Striga* sp., a parasitic weed that is a major scourge plaguing African smallholder farms. *Desmodium* produces two sets of compounds: one that stimulates the germination of *Striga* seeds and another that inhibits their growth after germination. Push-pull also improves soil fertility, moisture and overall soil health and reduces mycotoxins contamination, a major food safety hazard. The push-pull intercrops provide superior fodder for livestock. Most recently, the push-pull technology has been shown to control the fall armyworm (*Spodoptera frugiperda*), a major insect-pest threatening crops that was first reported in Africa in 2016. (*For more analysis of the push-pull benefits, see 4.3: Socio-economic and environmental impact of *icipe* technologies). Progress includes:
- **Third generation push–pull:** Previously, a climate-smart push-pull was developed incorporating greenleaf desmodium (*Desmodium intortum*) as an intercrop and *Brachiaria* cv Mulato II as a border crop. During this review period, *icipe* developed a third-generation push–pull with additional *Brachiaria* and African *Desmodium* species incorporated into the climate-smart version of the technology. Through a participatory process with farmers, *Brachiaria* cv Xaraes and Piata, were identified as the most stable and improved species that are more drought-tolerant and pest resistant, while retaining the key traits of the technology. *D. incanum* and *D. ramosissimum* were selected as the “push” plants due to their high drought-tolerance, biomass yield, and ability to flower and produce seeds across various agro-ecological environments.
 - **Vegetable integrated push-pull:** *icipe* studies have shown that *Desmodium* repels vegetable pests. The legume also attracts the natural enemies of the pests. Thus, *icipe* has begun to integrate farmer-preferred vegetables like kale, black nightshade, cabbage, cowpea, tomato and onion, into push-pull systems. The vegetables will supplement household nutrition and provide income during maize off-seasons. Impact assessments show that the vegetable integrated push-pull system is a profitable option for farmers, with a high net present value and benefit cost ratio (27:1). The system is particularly beneficial to women and the youth, who play a major role in the value chain.
 - In 2022, *icipe* with the support of the IKEA Foundation started to *harness the vegetable integrated push-pull technology and black soldier fly farming, into a One Health package* that will increase production of cereals, the main staples for most households; as well as high-value vegetables, poultry and fish, which will augment the region’s largely starch-based diets, thus countering malnutrition and hidden hunger while protecting the environment. The initiative will contribute to a resilient, circular, and regenerative food system, and create novel income generation and job creation opportunities especially for women and the youth, in eastern Africa.
 - **Scaling-up push-pull technology** through target-specific dissemination and impact pathways. During this period, *icipe* has aimed to address the most significant constraint in the adoption of the push-pull technology; the inadequate availability and affordability of *Desmodium* seeds. Functional networks of private sector, farmers and community-based seed producers, as well as market linkages between them and seed companies, have been established. Through continued extension programmes, primarily by the Technology Transfer Unit working with NARs, NGOs, the media and other partners, and directly with farmers, the adoption of the push-pull technology has more than doubled, from 150,000 farmers in 2017 to 350,000 farmers by end of 2022. From just four countries – Kenya, Ethiopia and Tanzania and Uganda in the previous period, the push-pull technology has been introduced into 14 new countries: Zimbabwe, Malawi, Zambia, Rwanda, Burundi, Burkina Faso, Congo, Mozambique, Togo, Benin, Cameroon, Senegal, Ghana and Mali. This brings the total number of countries where the push-pull technology is being used to 18.

- *icipe* studies have produced evidence on the resilience, sustainability and adaptability of the climate-smart pull-pull technology, its impact on soil conditioning, rhizosphere microbiome, plant-soil feedbacks and on maize phytochemistry. As discussed under the social-economic section, additional insights have been generated on return on investments, economic benefits, women empowerment, technology adoption. Various agronomic changes have also been tested to facilitate a higher success rate.
- ii. **Fall armyworm management:** For long, this destructive moth that causes devastating damage to almost 100 plant species, including cereals, grasses and a variety of horticultural crops was confined to its native origin, the Western Hemisphere (from the United States of America to Argentina). However, in January 2016, the fall armyworm was reported in Nigeria, and it has since spread at an alarming rate across Africa; its presence now is confirmed in most African countries. By 2022, the fall armyworm had caused an average annual loss of 36 percent in maize production alone; and a total economic loss of between USD 1– 4.6 billion per year in Africa. *icipe*, jointly with national and international partners embarked on basic and applied research to understand the ecology of the pest in Africa, to guide the development of sustainable management strategies suited for African conditions. The Centre has developed a synergistic, climate-smart, agroecological package that controls different stages of the pest.
- In 2017, the *icipe push-pull technology*, became the first documented, readily available technology that could efficiently manage the fall armyworm in an environmentally friendly and cost-effective manner. In 2022, the Centre published findings on the scientific mechanisms through which the technology conquers the fall armyworm. These results advance global knowledge on exploiting insect behaviour and stimulation and deterrent approaches in pest control.
 - With the significant support of development partners, government and regulatory authorities, as well as private sector actors in East Africa, *icipe* has developed a range of *biopesticides*, providing farmers in Africa with effective and environmentally safe alternatives for the management of the fall armyworm. Two *icipe* isolates of the insect-infecting *Metarhizium anisopliae* fungi: *ICIPE 78* and *ICIPE 7*, which had been commercialised by the Centre's private sector partner, Real IPM Biobest, as Mazao Achieve and Mazao Tickoff respectively, were found to be effective against the fall armyworm, and to work in synergy with the pest's natural enemies. In 2021, approvals were obtained for the label extension of Achieve OD (*ICIPE 78*) in Kenya. In 2022, the final approval was received for the label extension and registration permits of Mazao Achieve (*ICIPE 78*); and Mazao Detain (*ICIPE 7*), in Tanzania and Uganda. The ability to fast-track the biopesticides from the lab to the field in a relatively short time is testament to the importance of an enabling policy and regulatory environment for the release, registration and trade of agro-inputs. It succeeded because of a participatory process that involved public and private sector partners, policy and regulatory authorities, research institutions and other stakeholders.
 - *Natural enemies and other strategies:* Though the fall armyworm is an alien invasive pest, *icipe* has unravelled widely distributed native parasitoid species in Africa (namely *Telenomus remus*, *Trichogramma chilonis* and *Cotesia icipe*) and their ability to successfully parasitize and kill the invasive pest. The Centre has mass produced these parasitoids and released them in fall armyworm hotspots along with other eco-friendly management technologies to effectively manage the pest. *icipe* is working with farmers to augment the populations of the natural enemies. Other fall armyworm control strategies include community-based monitoring and early warning, trapping using sex pheromones, and the training of numerous stakeholders including extension officers, research assistants and community focal persons. These control efforts have helped to reduce the use of chemical pesticides and enhanced crop productivity. *icipe* has also been an active participant in major global and regional initiatives.
- iv. **Integrated pest management (IPM) packages** for pests of fruit trees, vegetables and staple crops, using other organisms like predators and parasitoids; biopesticides and botanicals; naturally derived attractants and repellents; and cultural practices like intercropping.
- During this period, *icipe* undertook *participatory and inclusive upscaling of the fruit fly IPM packages* among smallholder fruit growers in eastern Africa (Kenya, Ethiopia and Tanzania), and in Southern Africa (Malawi, Mozambique, Zambia and Zimbabwe), with a special focus on women and youth along the mango value chain. The TTU supported these efforts with massive awareness creation, dissemination of information through training materials in local languages, radio broadcasts and other media platforms, mobile and digital tools. These efforts have revitalised momentum for fruit cultivation. The Centre's postharvest hot water treatments of avocado and mango led to the first successful export of these commodities to the EU, in a long while. Novel knowledge has also been produced to strengthen surveillance of invasive species, predict breeding sites and basic research to enhance control.
 - *icipe* and partners have assembled, validated and implemented an eco-friendly management toolbox for *P. absoluta*, the invasive and highly destructive tomato leaf miner, which was detected for the first time in Africa in 2008 and it has since spread rapidly across the continent. A milestone was the release of a natural enemy (*Dolichogenideia gelechidivoris*), imported from Peru. An *icipe* biopesticide derived from strains of *M. anisopliae* (*ICIPE 20*), is being commercialised with Real IPM Biobest; supported by capacity building of farmers and other stakeholders.

- The Centre has also advanced strategies to control the invasive potato cyst nematodes (PCN). A prototype of a banana fibre paper technology that can control PCN and other pests has been developed for commercialisation by IITA, *icipe* and partners, with the support of BioInnovate Africa Programme.
 - An integrated pest and pollinators management project has provided knowledge on these two components, revealed pollination deficits and ways to address them, as well as leads for healthier agricultural landscapes for improved food security.
- v. **Commercialisation partnership for *icipe* biopesticides.** The RT witnessed an example of such a successful private-public partnership at Real IPM Ltd., which is based in Kenya, and is now a subsidiary of the multinational company Biobest (Westerlo, Belgium), which has commercialised several strains of *Metarhizium* spp. from *icipe* through a royalty arrangement. Multiple products (for example Detain, Achieve, Tick-Off) thus developed by the Centre have been commercialised and promoted for use in farms in several African countries (currently on >120,000 ha).

4.1.4 Environmental Health Theme

A key aim of the Environment Health Theme is to develop and promote innovations for the conservation of arthropods, while also harnessing their ecosystem services for better livelihoods and sustainable development of Africa and beyond. Over the years, *icipe* has been ingenious in exploiting insect biodiversity to develop holistic and inclusive livelihood alternatives for communities, especially those living in fragile or natural resource-rich ecosystems in Africa.

- i. **YESH and MOYESH:** During this review period, a key development has been a slant towards youth entrepreneurship. The Centre has combined its extensive experience in developing community-based enterprises on sustainable, modern beekeeping and silk farming, and Africa's extremely urgent need to create opportunities for young people. This vision commenced in earnest in 2016, when *icipe* partnered with the Mastercard Foundation to launch the Young Entrepreneurs in Silk and Honey (YESH) project, which runs until 2021. The initiative aimed to respond to Ethiopia's unemployment challenges, by benefitting unemployed and out-of-school youth in the country through entrepreneurship opportunities and access to technologies and practices, financial services, market linkages, etc. to establish successful small enterprises in beekeeping and silk farming. The apiculture component of the YESH project was implemented in the Amhara region, and the sericulture component in the Southern Nations, Nationalities and Peoples (SNNP) region. The YESH project spawned jobs for 12,780 young men and women through honey and silk enterprises. A total of 1,060 youth business enterprises were established, and 121 tonnes of honey and 16 tonnes of silkworm cocoons were produced. Approximately USD 1.4 million was generated from beekeeping, silkworm farming and complementary side businesses. The initiative put in place functional marketplaces for honey and beeswax. It also served as a platform for *icipe* to lead the development of a National Sericulture Development Strategy, at the request of the Ministry of Agriculture of the Federal Democratic Republic of Ethiopia.

In 2019, with the YESH programme still underway, in view of the significant progress and enormous potential, the Mastercard Foundation provided support for a much more extensive programme, the More Young Entrepreneurs in Silk and Honey (MOYESH), with project funds amounting to USD 56 million. This is the largest programme funding ever received from a donor by *icipe*. The MOYESH project, which covers the period 2019-2024 is being implemented in partnership with the Ethiopia Jobs Creation Commission (JCC). The initiative aims to see 100,000 young men and women in Ethiopia secure dignified and fulfilling work along honey and silk value chains. By end of 2022, the MOYESH project had created direct jobs for 67,191 young people in beekeeping and sericulture, which is 67 percent of the 100,000 target and 12 percent above the threshold set for this point of implementation. An additional 25,066 direct jobs were created through partner organisations providing inputs and service delivery. The youth partners have been aggregated into 6,818 cooperative enterprises (6,057 beekeeping; and 761 sericulture). The beekeeping enterprises are rearing a total of 80,224 bee colonies; they have produced over 1,093 tonnes and 59 tonnes of beeswax, generating the equivalent of USD 5.38 million. The project has enabled the enterprises to domesticate castor plants, establish high quality silkworm egg grainages, rear them and produce silk cocoons, and grade and process the cocoons into yarn. About 1,800 kg of silkworm cocoons have been produced, out of which 450 kilogrammes of yarn has been reeled and sold. Indirectly, through the MOYESH project, opportunities have been created for 548,512 people cumulatively, including input suppliers, trainers and agricultural professionals. The initiative has also bolstered finance, digital literacy and financial inclusion of partnering youth, and market development. Through the MOYESH project, 7,343 hectares of previously degraded land have been rehabilitated. The MOYESH project has become a model for holistic and inclusive job creation for youth in Africa, demonstrating resilient beekeeping, inclusive recruitment of youth, gender equity and inclusive value chains, finance, digital literacy and financial inclusion in beekeeping and silk farming.

- ii. **Domesticating stingless bees:** Stingless bees remain largely unfamiliar to many people. Also known as meliponines, stingless bees are smaller than honey bees, and as their name implies, they are incapable of stinging. This understated image of stingless bees belies their immense value, which includes their natural, highly-sought-after and highly-priced therapeutic products, such as honey, propolis and wax. Stingless bees are also superior

pollinators. Since the mid-2000s, *icipe* has pioneered meliponiculture, the domestication of stingless bees in Africa, with the goal of creating income generation opportunities for communities while conserving and regenerating this mighty resource. *icipe* research has revealed the presence of 38 endemic stingless bee species belonging to six genera, which differ in their nesting behaviour and honey productivity. These studies have shown that stingless bees can efficiently pollinate various fruits and vegetables. They lead to better fruit quality of cucumber and seed quantity are achieved from a single flower visit, due to their longer probing time compared to honey bees. Unlike honey bees, stingless bees can be commercially used to pollinate crops cultivated in greenhouses. About 35 of the stingless bees identified by *icipe* can be easily domesticated. The non-stinging nature of these bees and low labour requirement offer potential to equally engage youths, men and women in meliponiculture in Africa. *icipe*'s ongoing research is investigating the physico-chemical and bio-functional properties, in vitro production of queens and mass colony production, and food resources used by stingless bees from different ecological zones in Africa, to better understand how these bees rely on plant resources. *icipe* continues to build knowledge on stingless bees' diversity in Africa; and to link the quality characteristics of their honey with influencing factors such as the bee species, ecosystems and processing methods. The Centre is also establishing standards for stingless bee honey.

- iii. *icipe* sustainable honey and stingless beekeeping initiatives during this review period extended from the Indian Ocean island nations (the real worth of the activities was noted during the COVID-19 pandemic, when the tourism sector was down); Zanzibar island (participatory beekeeping project for ecological protection of mangroves); Kenya and Ethiopia (diversified livelihoods and incomes of pastoral and agropastoral communities; and harnessing beekeeping potential in the arid and semi-arid lands). The Centre has also contributed to policy and regulatory frameworks in several countries; regulations for organic honey certification; quality production and fair trade of honey.
- iv. *icipe* has a mandate of **conserving insect and arthropod biodiversity**. This has led to the discovery of many interesting new species and provided insights into the geographical distribution of various insect groups, primarily Hymenoptera and Diptera. The centre has established a pioneering, well curated and long-term collection of insects in East Africa. The physical collection is supported by a comprehensive database with complete geographic and temporal data and images for each specimen. The collection database includes about 65,000 unique specimen records, each of which has complete positional and temporal data as well as preliminary identifications.

4.2 Insects for Food, Feed and Other Uses Programme

icipe began to consider insects for food, feed and other uses (INSEFF) as a new strategic area of research in 2012. From 2013, the programme gained significant momentum, and currently INSEFF stands out as a major and exciting area of focus at the Centre. As a pioneer in this sector, *icipe*'s role is vital to promote a novel industry that reliant on a natural food source for a sustainable world. The INSEFF programme focusses on cutting-edge science and innovations within a One Health framework, to contribute to the transformation of the current food system into a more sustainable and vibrant circular economy. Ground-breaking findings from INSEFF during this review period include:

- i. *Optimised rearing protocols and substrates for cost-effective, sustainable mass-rearing harvesting, and post-harvest techniques that conserve nutrients and ensure food safety* – for 25 edible insect species, including black soldier fly, cricket, fruit beetle and grasshopper. Mass rearing units have been established at *icipe*, where they serve as demonstration and training sites. The Centre has also designed simple extraction methods to produce novel, high value products such as insect oils, enzymes and pharmaceuticals. These strategies have been adopted by smallholder and medium scale enterprises in eastern Africa, leading to an emerging small industry across East Africa.
- ii. *Innovations to harvest and reverse negative impact of insects*: Examples include a low-cost cordless and portable suction backpack trap developed by *icipe*, which can be used in large-scale daytime collection of locusts during outbreaks. This tool can be easily operated by community members who understand the terrain and are able to identify and harvest roosted adults (at night) or moving hopper bands. These environmentally friendly strategies have dual benefits of protecting crop losses by locusts, while safely harvesting them for use as food and feed. *icipe* is also developing a pheromone trapping system for harvesting adult palm weevils (*Rhynchophorus phoenicis*), to reduce their damage to host crops and their potential use as food.
- iii. *Mainstreaming nutritious edible insects and their products into food systems to overcome malnutrition*: In Africa, insects have traditionally been consumed by numerous communities. *icipe* has built on this ethno-knowledge to characterise the nutritive profiles of several edible insects. These studies have also demonstrated the nutritional superiority of insect oils, which, in comparison to plant oils have better nutrients that are digested equally well by our bodies, and are richer in omega-3 fatty acids, antioxidants and vitamin E. *icipe* has also created a blueprint for using insects in food-to-food biofortification. For example, in 2022, in a game-changer for nutritional security in Africa, *icipe* used insect nutrients to transform African porridge from a basic, often low-nutrient meal, into a super-food that meets and exceeds micronutrient requirements for people. The researchers fortified finger millet with high-quality nutrients from an edible African cricket known as *Scapsipedus icipe*; and the grain of amaranth, an

indigenous vegetable that is widely grown across the continent. Widely farmed across Kenya, the cricket, *S. icipe*, was discovered by the Centre in 2018 as a new species in science. *icipe*'s studies have shown that the cricket is significantly rich in crude protein and fat, which, respectively, make up 57 percent and 36 percent of its dry body weight mass. The insect is also rich in essential amino acids, minerals and vitamins, with 88 percent of its nutrients being digestible by the human body. As a result, insect-based food-to-food biofortification is now being introduced in schools and refugee feeding programmes.

- iv. *Insects as alternative, more affordable, nutritious (higher lysine and tryptophan content) protein options for animal feed, thus increasing productivity of livestock, fish and poultry.* In particular, *icipe* has demonstrated that black soldier fly larvae or the proteins derived from them, can be used safely as components in animal feeds. This knowledge has led to a new generation of insect-based feed formulations with high (40-60% higher) protein, which have been widely tested in poultry, fish, pigs and pet food sectors, especially across eastern Africa. For instance, 7% of Kenya's annual animal feed protein is currently being met through insect proteins, with projections that in two to three years, such integration could go up to 40%. In poultry, such feeds have been proven to improve growth performance, the quality and quantity of meat and eggs, and overall profitability for farmers. The use of insect proteins in feed is also freeing up conventional options like fishmeal and soybean as food for human consumption. Moreover, *icipe* studies have demonstrated that insect-based feeds increase the wealth of beneficial bacteria in the gut of poultry, thus promoting the overall health and growth of the birds. These findings are significant against the ongoing quest, in Africa and globally, to re-evaluate and reduce the use of antibiotics in poultry farming.
- v. *Effective recycling of organic wastes high-value organic fertilisers for improved soil health and crop productivity.* Globally, there is growing interest in using insects to recycle organic waste into high-quality frass fertiliser, thus creating a circular economy approach. Insect frass fertiliser or organic manures enriched with it provide novel options for plant nutrients including improved soil fertility by contributing to nitrogen, phosphorus and potassium, and bio-stimulation through enhanced nutrient release in plants and thus ensuring food security. In particular, *icipe* has demonstrated the superiority of frass fertiliser developed using black soldier fly (BSF) larvae. The Centre has developed a low-cost technology for recycling agro-industrial waste using BSF, to produce high-quality frass organic fertiliser. Among other attributes, the technology shortens the compost maturation period, and helps generate a product that increases seed germination, which implies that the compost generated is free of phytotoxic. The Centre has also identified an additional eight insect species that could be employed to produce high quality frass fertiliser.
- vi. *Additional novel insect-based products.* For example, chitin, the scaffolding material around insects, can trigger plant defence genes and also control nematodes and soil-dwelling insects, and it can also be used as a soil amendment. These products help to reduce the use of chemical inputs, especially pesticides, which may have adverse environmental and health effects. The Centre is also advancing bioconversion by insects to develop polystyrene-degrading bacteria associated with the gut of mealworm. and as the basis for novel antimicrobials against superbugs. This innovation has the potential to offer a solution to the plastics pollution threatening the world's oceans.
- vii. *Partnerships with policymakers and diverse stakeholders,* have been formed leading to the development of policies and national standards for safe, equitable use and trade in edible insects, in Kenya, Uganda, Rwanda, Tanzania and Ethiopia. More recently, the INSEFF programme has established a close and strategic partnership with the African Organization for Standardization (ARSO), to promote the development and harmonisation of continent-wide standards and conformity assessment for edible insect-based products and insect-composted organic fertiliser.
- viii. *Knowledge acquisition, capacity building and financial literacy to scale-up insect farming:* *icipe*'s efforts have been backed by massive awareness raising and training efforts, a wide network of partnerships, and capacity building with a focus on youth and women, private sector actors, numerous other stakeholders and the general public, on the nutritional, economic and environmental benefits of insect-based technologies. This has resulted in the emergence of small- and medium-scale, insect-based enterprises that are producing a range of innovative products. The INSEFF activities have been featured in close to 500 news articles in the media, in 15 languages with a reach of over 3 billion people. The INSEFF programme has partnered with over 200 organizations in more than 60 countries around the world. Over 57,000 people have been trained on how to rear insects and process them efficiently, leading to the formation of 1,400 green, small and medium enterprises.
- ix. *Strengthening insect-based public private partnerships and generation of gainful and trade to green micro, small and medium enterprises in Africa,* resulting in over 1,400 SMEs that are producing insect-based feed; production of over 9,000 tonnes of insect-based feed for 4.7 million chicken per year. Overall, *icipe*-led insect farming is becoming a transformative force in creating ingenious employment and income generation opportunities especially for women and youth, thus taking pressure off scant land resources, and circumventing a range of challenges associated with traditional agricultural activities. Moreover, evidence shows that insect-based enterprises can be undertaken with minimal inputs. Therefore, they are ideal for women, young farmers and low-income households,

who are often constrained by limited access to agricultural resources. Mainstreaming insect farming pre-empts seasonal and unsustainable harvesting of this highly valuable resource from the wild, which boost its biodiversity, as well as overall ecosystem health. This has multiple benefits for agriculture, such as pollination and natural control of pests. The RT visited one such enterprise where the *icipe* technology has been put into practical commercial use; Zihanga Ltd, Kenya, a socially responsible company committed to reducing waste and promoting sustainable practices, founded by a young entrepreneur, Nicholas Mareve. The company recycles over 1000 tonnes of organic waste each year to make insect protein meal, organic pesticides and fertiliser. Further, it trains other small entrepreneurs on sustainable agriculture practices, to promote the technologies acquired from *icipe* through the community.

- x. These extensive achievements and pioneering research and development (R&D) activities on insects for food, feed and other uses by *icipe* and partners have been globally recognised, not least through the award of the Curt Bergfors Food Planet Prize in 2020 (<https://foodplanetprize.org/initiatives/prizewinner-icipe-inseff/>). Currently the largest accolade of its kind in the world, the accolade acknowledges ground-breaking initiatives that offer solutions to tackle the Food Planet Challenge; the need to keep a rapidly growing world population alive and well-nourished – without destroying the Earth.

4.3 Socio-economic and environmental impact of *icipe* technologies

A notable attribute of the *icipe* R&D activities during this review period is the comprehensive assessment of socio-economic and environmental impacts of insects in general, and, specifically, the Centre's technologies. This rigorous evaluation is thanks to a much stronger Social Sciences and Impact Assessment Unit (SSIAU). Set up in 2012, the Unit's capacity for critical analysis has been progressively bolstered especially over the past five years, to provide insights on the dissemination, adoption, economic benefits and gender inclusiveness of *icipe* technologies and strategies. The SSIAU also has the responsibility of implementing the Centre-wide monitoring and valuation (M&E) and gender strategies. Examples of its insights, which have also been published in high quality peer-reviewed journal articles, include:

- i. *Value of the fruit fly IPM packages.* An earlier study (2016) demonstrated the effectiveness of the packages in curtailing fruit fly infestations, leading to increased yields and decreased pesticide usage. In Kenya, applying bait sprays resulted in an 86% reduction in fruit fly infestation and an approximately 71-75% yield increase. Similar studies reported up to a 46.3% decrease in pesticide expenses in mango production and a 22.4% - 45% increase in net mango income. Studies conducted during this review period demonstrated an annual economic surplus benefit of USD 18.79 million from the IPM R&D activities. With an assumed 24-year adoption period, a 50% maximum adoption rate, and a 7% discount rate, the net present value of the IPM research is USD 75 million (USD 2.35 million annually), featuring a 29% internal rate of return and a 27:1 benefit-cost ratio. Furthermore, the findings suggest that the IPM packages could lift approximately 1.7 million individuals (or 72,642 annually) out of poverty between 2007-2030.
- ii. *Impact of the *icipe* push-pull technology and IPM on the environment, production and poverty in Kenya and Uganda.* This report provides the first regional-level estimate of the effects of these two technologies. The findings indicate that approximately 640,000 households have become food secure, about 445,000 have escaped poverty, and an estimated USD 3.2 in value has been generated for every dollar invested. Additionally, the technologies have helped to prevent the use of over 11 million litres of pesticides, thus protecting the health of people and the environment. They have also contributed to the sequestration of around 2.7 million tonnes of carbon dioxide equivalent.
- iii. *Impact of *icipe* mosquito and malaria control measures:* With the growing declining impact of traditional methods like insecticide-treated bed nets and indoor spraying in mosquito and malaria control, this study aimed to explore the success of the *icipe* integrated vector management (IVM) strategies. The findings show that in Zambia, house screening reduced malaria prevalence and episodes and sick days due to the disease. The study also showed greater impact of malaria on adults than children. Economically, house screening increased labour supply and household income, particularly for women. A cost-benefit analysis showed that the private benefits of house screening exceeded the costs. In Ethiopia, house screening was combined with gain-framed and loss-framed health messaging. While screening alone provided positive net benefits, combining it with health messaging greatly boosted these benefits. Loss-framed health messages had a more durable impact on behaviour and health outcomes, eliminating infection rates and sick days among treated households. The Unit also demonstrated the impact of combining education campaigns and biolarviciding using *Bacillus thuringiensis israelensis* (*Bti*) and increased household income in Ethiopia from a One Health perspective, especially when combined with other health interventions (plant, animal, and environmental health). The findings show that the productivity effects of malaria were greatest when women and children under 14 fell sick.
- iv. *Impacts of fall armyworm on maize production:* Between 2017 and 2019, the pest caused an average annual loss of 36% in maize production in Ethiopia, amounting to 0.67 million tonnes of maize (0.225 million tonnes per year),

with a total economic loss of USD 200 million, or 0.08% of the gross domestic product. A crucial finding of this study is that the insecticides used to control the fall armyworm have pronounced toxic effects, markedly more on the environment than people. The study underscores the pressing need for impactful interventions for pest control to mitigate these substantial losses.

- v. *Impact of trypanosomiasis on crop-livestock production, economic loss and poverty in Ethiopia:* The researchers used a unique panel dataset to estimate how the disease affects livestock deaths, production costs, and crop production. These estimates were then used to evaluate the disease's total economic loss and its implications on poverty in the study districts and the country. The study indicated that trypanosomiasis increased the value of livestock deaths by 33% and production costs by 63%. Crop production decreased by 14% when trypanosomiasis and oxen death coexisted. The direct economic loss was estimated at about USD 58,300 per annum in the study districts, with an estimated countrywide economic loss of about USD 94 million per annum. This significant economic loss, if countered, could have lifted about 9000 and 200,000 people in the study districts and the country, respectively, above the national poverty line per annum. Thus, trypanosomiasis is a major production constraint which requires policy attention. Further, the researchers analysed the impact of adopting the tsetse repellent collar technology. The findings show that this innovative solution could substantially provide an annual economic boost of USD 78–869 million across 18 African countries. These results make a case for investment in the technology, to reverse the extensive economic losses induced by trypanosomiasis.
- vi. *Insects for food and feed and other uses* including knowledge, awareness and perceptions of farmers, producers and private sector actors on insect-based feeds; economic benefits of insect farming and insect-based products; consumer perceptions and preferences on insect consumption, and products from animals reared on insect-based feeds; key variables for decision by consumers to purchase insect-based products; and barriers to the use of such products and necessary interventions. Socio-economic studies show that there is rising acceptance among consumers for products, like eggs and meat, produced using insect-based feeds.
- vii. For instance, the Unit's studies established that by substituting the conventional feed sources with 5-50% black soldier fly larvae meal, up to 2-18 million tonnes of biowaste is recycled. This process produces between 1.8-139.8 million kg of insect frass (biofertilisers), creates almost 25,000-250,000 new jobs per year, and has the potential to feed nearly 0.5-5 million people per year in Kenya alone while improving the overall economy and bringing millions of people out of poverty. Substituting the conventional feed sources with 5-50% black soldier fly larvae meal, up to 2-18 million tonnes of biowaste is recycled. This switch produces between 1.8-139.8 million kg of insect frass (biofertilisers), creates almost 25,000-250,000 new jobs/year, and has the potential to feed nearly 0.5-5 million people per year in Kenya alone while improving the overall economy and bringing millions of people out of poverty. Further, the Unit has demonstrated that 5-50% replacement of conventional protein and energy in animal feed with insect meal in the Kenyan poultry sector alone can generate an economic benefit of USD 69-687 million. This translates to reducing poverty in 0.32 - 3.19 million people, while increasing youth and women employment by 25,000 - 252,000 people, annually. Also, over 0.24-2.24 million tonnes (mt) of organic wastes will be recycled to 1.8-18.4 thousand tonnes of organic fertilizers. This would increase the availability of fish, soya bean and maize that can feed 0.47 - 4.8 million people in Kenya.
- viii. *Economic and ecological values of insect frass fertiliser:* the studies show that that sourcing waste substrate for insect rearing accounts for 81 – 90% of the total black soldier fly production cost. The use of frass fertiliser as an additional value-added product would increase farmer's net income by 5 – 15 folds compared to insect farming alone. Production of one megagram (mg) dried insect larvae (USD 900) would generate 10 – 34 mg frass fertiliser worth USD 3,000 – 10,200. Maize grown on plots treated with frass fertiliser yielded 29 – 44% higher net income than plots amended with commercial organic fertiliser. Additionally, the use of self-produced frass fertiliser by smallholder insect farmers for maize production would generate 30 – 232% higher net income than in the case of farmers outsourcing similar products. From a circular economy perspective, insect farming justifies the opportunities for future investments that would enhance sustainability for agricultural and food systems, especially for smallholder farmers in low- and middle-income countries.
- ix. *Effects of shifting resources from pollination-independent to pollination-dependent crops* on nutrient deficiencies, particularly on micronutrient deficiencies. The research provides substantial evidence that increasing the cultivation of pollination-dependent crops significantly reduces nutrient deficiencies. This strategic change also boosts crop income while ensuring stable macronutrient production. These crucial findings strongly support the increased investment in pollination-dependent crop production. This shift could strengthen nutritional security across Africa, affirming the vital role of pollination-dependent crops in enhancing the region's food and nutritional resilience.
- x. *Correlation between women empowerment and nutrition:* The unit demonstrates that women's empowerment positively impacts dietary diversity, regardless of technology adoption status. Furthermore, women's empowerment bolsters the positive effects of technology adoption on dietary diversity. The synergy of women's empowerment and technology adoption is spotlighted as a holistic approach to augmenting women's nutritional status and overall welfare. Additionally, the adoption of push-pull technology further augments consumption expenditure aligned with

women's preferences and facilitates more efficient labour use, enabling women to conserve efforts in activities such as weeding, land preparation, and planning. Push-Pull technology adoption significantly reduces labour requirements during ploughing, weeding and threshing but significantly increases harvesting labour. In comparison to men, women save more labour hours during weeding and threshing period but less during ploughing. Adoption of Push-Pull technology increases child education investment and shifts household expenditures towards goods associated with female consumption preferences.

4.4 Data Management, Monitoring and Geo-Information Unit

In 2019, *icipe* established the Data Management, Modelling and Geo-Information (DMMG) Unit, which has a four-fold mandate. First, the Unit is responsible for the establishment and enhancement of the Centre's data management and data sharing workflow. This includes setting up the relevant policies, rules and governance mechanisms in compliance with international standards. Second, the DMMG Unit strengthens the analytical skills of *icipe* teams and partners. Third, the Unit is mandated to develop a research niche to conceptualise and establish next generation decision-making tools, models, analytics and approaches for the management of crop pests and disease vectors, and the sustainable use and conservation of beneficial insects. Four, the DMMG Unit supports *icipe*'s 'One Health' vision and resource mobilisation goals. This is by reinforcing the alignment of the institution's scientific data infrastructure and practice to universal standards such as the FAIR principles of data management, while also showcasing elements of open data, open science and reproducible science.

The Unit has grown rapidly over the past three years and currently has a team of 53 members, which includes 9 scientists, 12 research officers, 12 PhD students, 5 MSc students, one consultant and 14 interns. The internship programme, which was introduced in 2020 at the DMMG, has so far trained 50 young graduates, some of whom are now working as staff at *icipe* and in other organisations. Accomplishments include:

- i. Development and implementation of the *icipe* Data Research Management and Archiving Policy. Aligned to the policy is the Centre's data infrastructure, which has several interconnected components, namely, common ontology, legacy data, data management plan, digital data collection tools, the data warehouse, and a software version data management tool (GitHub). Google analytics accessibility metrics of the *icipe* information systems show that the Centre's data is accessed globally, at a fast-rising rate.
- ii. In 2020, East Africa experienced the worst desert locust outbreak in decades. To contribute to the management of this crisis, the DMMG Unit obtained 2,500 records of desert locust nymphs. The research team applied machine learning techniques and combined environmental variables in predicting the potential breeding areas of desert locusts in East Africa. It demonstrated that large areas of Kenya, north-western and north-eastern Uganda, middle and central regions of South Sudan have the highest potential in providing conducive breeding for the pests. Such specific knowledge of these insect-breeding sites will enable better action and reduced financial cost in the implementation of preventive measures to control future locust outbreaks.
- iii. The Unit used long-term climate data and time-series remote sensing and vegetation variables to explain the role of landscape structure and fragmentation on the integrity of honeybee colonies. Further, the Unit has developed the first ever predictive ecological niche model for stingless bees in Kenya. The team has also created a novel methodological framework to couple crop and insect pest models. Using the model, they have produced worldwide maps of the temperature- and carbon dioxide- dependent damage in maize, combined with yield losses due to insect pests, under several climate change scenarios.
- iv. To understand the resilience of the push-pull technology, the DMMG team assembled long term data from push-pull and non-push- pull fields in western Kenya, covering 34 cropping seasons (2005 – 2016), and demonstrated that more than 20 years since the technology was first introduced, stemborers and the parasitic Striga weed have not adapted to overcome its effectiveness. In fact, the robustness of the push-pull technology has improved due to emerging properties within it. Indeed, the RT witnessed such a field during a visit to the Homa Bay area near Lake Victoria.
- v. In support of the malaria transmission blocking symbiont research, the team is using an integrated system dynamics simulation model to explain the interactions among people, the malaria vectors and parasites, the environment, and implications for malaria transmission; and an individual based modelling system to predict the changes in malaria characteristics after interventions using *Microsporidia MB*.
- vi. The DMMG Unit is also conducting disease modelling in Kenya, in view of the continued continent-wide outbreaks of dengue fever, an NTD whose virus is mainly transmitted by *Aedes aegypti* mosquitoes. The findings will support targeted preventive and control measures.
- vii. Through studies conducted in Shimba Hills National Reserve, Kenya, between 2017 and 2019, the team used a species distribution model linked with satellite-derived data to predict potential breeding and foraging grounds of the *Glossina pallidipes* tsetse fly species, the vector of African animal trypanosomiasis. This knowledge will guide the design and deployment of cost-effective, large-scale tsetse control tools.
- viii. The Unit is also intensifying data science capacity building at *icipe*, while also responding to an increasing number of requests from across Africa and the globe, to boost capabilities, share experience and create awareness.
- ix. DMMG is considering the use of Digital Twin technology, which is the representation of an intended or actual real-world system or process, essentially a virtual counterpart of the physical system. The technology can be used, for

example, to model and simulate the behaviour of bee or mosquito colonies under different conditions. While it is already being used in various industries, its potential value to *icipe* is being explored.

4.5 Capacity Building and Institutional Development Programme

4.5.1 Postgraduate and postdoctoral training: Capacity building of individual researchers, institutions and communities in Africa has always been an integral part of the *icipe* R&D activities. Primarily, this goal has been achieved through the Centre's highly successful postgraduate (MSc and PhD) training programmes, which enable young researchers from across Africa and beyond to acquire world-class training and hands-on research experience in insect-science and related fields. The *icipe* African Regional Postgraduate Programme in Insect Science (ARPPIS), provides 3– 4-year doctoral research fellowships; while the Dissertation Research Internship Programme (DRIP), is an umbrella for MSc and PhD scholars of any nationality, enrolled in African or non-African universities, to pursue all or part of their research at *icipe*. In both cases, the scholars are jointly supervised by *icipe* scientists and university faculty, with degrees awarded by the host university. The scholars make outstanding discoveries, thus contributing to the global knowledge hub, to *icipe* R&D activities and to sustainable development. The *icipe* postdoctoral fellowship programme provides opportunities for doctoral graduates to undertake research at the Centre to develop their research skills and careers, and collaborative research programmes.

Over the past five years, *icipe* has aimed to transform the capacity development efforts from functional training to high quality mentoring. This approach is intended to lay a stronger career foundation, while supporting research capacity in Africa more effectively. In addition to technical skills in specific research areas, the *icipe* postgraduate programme provide much broader academic and professional skills, including research compliance and ethics, science paper writing, proposal writing, communications and research leadership.

During this review period, *icipe* took steps to ensure even stronger embedment of the capacity building and institutional development activities across all projects and programmes, especially towards One Health skills development. The Centre also intensified efforts to enhance geographical representation; and to pursue gender equity and more participation of women.

Statistics during this review period clearly demonstrate the Africa-wide impact of the *icipe* capacity building programmes. A total of 97% of the postgraduate scholars hosted by the Centre between 2018 – 2022 represented 24 African nationalities, while the remaining 3% were from 8 non-African countries. Within the PhD programmes, 42% of the scholars were Kenyans, 56% from the rest of Africa, and 2% from outside the continent. A total of 79% the MSc scholars were Kenyans, 17% from the rest of Africa, and 4% from outside the continent. The *icipe* postgraduate scholars were enrolled at 39 African universities and 23 non-African universities. A total of 62% of the PhD scholars were registered at universities in Kenya and South Africa, and 81% of the MSc scholars were enrolled at universities in Kenya. A total of 265 new scholars joined the *icipe* postgraduate programmes. Each year, *icipe* had between 164 and 243 postgraduate scholars at different stages of their MSc and PhD programmes (see Table 1), the majority of whom were based at the *icipe* Duduville and iTOC Mbita campuses. A total of 45 ARPPIS PhD, 38 DRIP PhD and 105 DRIP MSc fellows completed training and graduated between 2018 – 2022 (see Table 2). Overall, 45 – 48% of scholars in 2018 – 2022 were women. The drop-out rate from the programme was minimal; only one DRIP MSc and 8 PhD scholars withdrew before completing their programmes.

The *icipe* capacity building programmes pivot the young researchers, through world class training and skills, and also enables them to access the global reward system, which includes resources, knowledge and recognition. During this period, the scholars received close to 100 external awards.

The German Academic Exchange Programme (DAAD) has been a major contributor of the *icipe* PhD scholarships, complemented by various other bilateral donors that fund the Centre's R&D activities. However, in 2022, perhaps due to the global economic downturn including the war in Ukraine and subsequent reconstruction, DAAD faced budget cuts of the order of 50% from the German Foreign Office, leading to a reduction in the number of DAAD scholarships to *icipe*. In 2022, *icipe* received only 3 scholarships, compared to the 5-6 received annually, previously.

Table 1. Total number of scholars engaged in *icipe* postgraduate programmes in 2018 – 2022

Programme				
Year	ARPPIS PhD	DRIP PhD	DRIP MSc	Total
2018	48	42	74	164 [46% women]
2019	50	46	115	211 [46% women]
2020	44	40	130	214 [48% women]
2021	38	38	156	232 [45% women]
2022	36	37	170	243 [45% women]

Table 2. Number of postgraduate scholars completing in years 2018 – 2022 and current scholars

Programme				
Year of graduation	ARPPIS PhD	DRIP PhD	DRIP MSc	Total
2018	4	12	18	34
2019	11	8	14	33
2020	13	6	17	36
2021	11	8	28	47
2022	6	4	28	38
Total graduates	45 [44% women]	38 [50% women]	105 [49% women]	188 [48% women]
Current scholars *	30 [27% women]	33 [42% women]	142 [51% women]	205 [46% women]

* As of December 2022

Between 2018 – 2022, the Centre hosted 39 postdoctoral fellows for periods of 1-3 years, across its 4Hs Themes and programmes. These fellows represented 10 African countries and 2 non-African countries. Postgraduate and postdoctoral fellows made a significant contribution to the research outputs of *icipe*. For example, of the 961 journal articles published by *icipe* in 2018-2022, 47% of them were lead-authored and 11% were co-authored by postgraduate and postdoctoral fellows.

4.5.2 Institutional strengthening: *icipe* aims to increase the ability of diverse stakeholders to produce and use scientific knowledge, and to effectively adopt technologies. Simultaneously, the Centre strengthens the capacity of African universities, as well as national research and innovation systems. Each year, *icipe* holds numerous training courses, workshops and other events for research scholars and scientists, research and development collaborators, farmers and extension workers, and other stakeholders. Between 2018 and 2022, *icipe* conducted 567 workshops and other training events for 70,143 participants (57% women, 43% men). Training was held in 21 African countries. The training covers a

range of activities, from basic and strategic research, technology development and validation, and technology implementation and commercialisation.

4.5.3 Information Resource Centre

Located at the Duduville campus, the *icipe* Information and Resource Centre has a seating capacity of 45 people and is operated by two full-time staff supported by interns. During the review period, the facility continued to provide effective and efficient support to *icipe* researchers and scholars over the review period. About 4,500 books, theses, reports among others, were added to the Centre's print collection. In 2018, a digital repository was created for all *icipe* research outputs, and in 2022 an additional repository was set up for RSIF. A total of 1,831 documents have been uploaded to these two repositories.

During the review period, the Information Resource Centre provided effective access to over 20,000 e-journals and 300,000 e-books through the Kenya Library and Information Services Consortium (KLISC), the Research4Life resources and the Centre for Agriculture and Biosciences International (CABI) resources, among others. The facility recorded over 2,000,700 resources usage and literature retrieval requests. All the digitalized MSc and PhD theses and dissertations produced by *icipe*-based scholars were also freely accessible through the repositories. In 2018, the Resource Centre acquired the Turnitin plagiarism detection software, which has been used for over 10,000 similarity checks on manuscripts, grant proposals, theses and dissertations to promote scholarship and authorship integrity.

The Centre continued to run its much-valued information literacy training course for new scholars and researchers. This course is mandatory for all CBID and RSIF scholars. In 2018 – 2022, 14 training sessions were held for 580 participants. The Information Resource Centre also assisted in capacity building of the libraries of the RSIF African Host Institutions (AHUs).

4.6 Scientific Publications

As a non-profit, research for development organisation with a mission to improve food and nutritional security in the SSA, *icipe* has put in place strong performance metrics for internal assessments and to track the Centre's progress towards envisioned organizational outputs. Over the past five years, *icipe* has greatly improved its publications record. The Centre has published high-quality, innovative information that is central to its food security, health and development mission. Between 2018 and 2022, *icipe* published 964 peer-reviewed journal articles (Table 1), a 49% rise from the 646 journal articles published during the previous IPER period (2013 –2017).

The number of publications has especially increased markedly over the last two years of this review period (2021 – 2022). As expected, the number of citations for the 2018 articles were greater than for 2022 articles, due to the higher lifespan of the former. *icipe* has prioritised publishing in open access journals or journals with open access models (Table 3). About 81% of the *icipe* journal articles are published in either open access or open access model journals. Datasets from the Centre are also available on freely accessible, discoverable and secure repositories (such as Dryad).

Table 3: Summary of Publications (2018 – 2022)

Item	2018	2019	2020	2021	2022	Total (2018-2022)
Journal articles (a)	148	137	153	261	265	964
Book chapters /Proceedings (b)	17	9	20	12	16	74
Total (a) + (b)	165	146	173	273	281	1,038
Non-refereed publications	108	144	200	22	75	549
Publications Metrics						
Open access articles	116	118	121	210	217	782

Item	2018	2019	2020	2021	2022	Total (2018-2022)
Articles in Journals with IF ≥ 2	87	91	103	179	193	653
Articles with NARS	51	32	47	86	110	326
Total citations	4,992	3,720	2,999	2,840	1,059	15,610
Total Full text views (downloads)	239,260	366,724	350,894	532,195	1,223,559	2,712,632

About 67% of *icipe*'s refereed articles were published in journals with an impact factor (IF) of 2 and above. The work of the Centre also appeared in the very high IF (ranging from 10.85 to 63.8) journals in each year. The number of articles published with partners from NARS has increased markedly during the last two years while publication of results in non-refereed journals decreased during the same period.

4.7 Awards and Recognitions

Over the period of this review, *icipe* and its staff received 154 national, regional and international honours, awards and recognitions, an average of 30 per year, for outstanding scientific research, professional services on various boards and advisory panels, participation in major global initiatives and on international juries of key science awards. A few noteworthy ones are listed below.

In 2020, *icipe* was awarded the prestigious, USD 1 million Curt Bergfors Foundation Food Planet Prize in recognition of its pioneering insects for food and feed and other uses. *icipe* shared the prize with Sanergy, a Kenya/United States-based organisation and a partner of *icipe*. The Food Planet Prize is the largest monetary award in the global food arena in recognition of innovative solutions that can help us shift to sustainable food systems within a ten-year timeframe.

- In 2022, Dr Segenet Kelemu was awarded the title of *Officier de L'Ordre National du Mérite* (Officer in the National Order of Merit) by the President of the French Republic. In 2018, Dr Segenet Kelemu, *icipe*'s DG, was selected by Bill Gates as one of five 'heroes in the field' for using their talents to fight poverty, hunger and disease, while providing opportunities for the next generation. In the same year, she received the 2018 Women of the Decade award from the Women Economic Forum for outstanding leadership in the Natural and Sustainable Ecosystems category.
- Menale Kassie was awarded the 2022 TWAS Siwei Cheng Award in Economic Sciences, for advancing understanding of the process and impacts of multiple-technology adoption in complex social and agricultural environments in sub-Saharan Africa (SSA).
- Dr Jeremy Herren, scientist and leader of the *icipe* SymbioVector Project, was selected as one of ten winners of the Falling Walls 2021, in the Life Sciences category.
- Dr Sunday Ekesi, Head, Capacity Building and Integrated Sciences, was selected as a Fellow of the Entomological Society of America (ESA), the largest organisation in the world serving the professional and scientific needs of entomologists and individuals in related disciplines. He also received the Distinguished Scientist Award, one of four awards given annually by the ESA International Branches.
- Dr Baldwyn Torto, Head of Behavioural and Chemical Ecology Unit, was awarded the 2019 Agropolis Louis International Prize for Food and Agriculture under the Outstanding Career in Agricultural Development category.
- In 2019, the Young Entrepreneurs in Silk and Honey (YESH) project, which had been implemented from 2016 to 2020, received a special mention in the International Innovation Award for Sustainable Food and Agriculture. This award, funded by the FAO and the Federal government of Switzerland, recognized the YESH project in the category of innovations that empower youth in agriculture and food systems.

5. BIOINNOVATE AFRICA PROGRAMME

Over 58% of the population of SSA lives in rural areas, depending directly on biological resources for food, fuel, medicine and other uses. Without value-addition through science and innovation, the biological resources continue to be used in raw form, and significant portions are disposed of as waste.

Funded by the Swedish International Development Cooperation Agency (Sida), BioInnovate Africa Programme is a regional science and innovation-driven initiative that was established in 2010. The Programme assists eastern African countries to benefit from revolutionary advances in biosciences, to add economic and social value to biological resources. The aim is to strengthen the capacity of universities, research institutes and firms to translate biologically-based ideas, inventions and technologies into new practical solutions that address development challenges in the region. BioInnovate Africa Programme has three thematic areas: (i) value addition to agriproducts and other bioresources (ii) biowaste conversion and (iii) biobased healthcare products.

In October 2016, Sida and *icipe* signed a cooperation partner agreement, for the Centre to implement BioInnovate Africa Programme phase II (November 2016 – March 2022). *icipe* has become a true home for the Programme based on synergies in the vision of working with researchers, policymakers and private sector actors towards inclusive innovations growth for socio-economic transformation Africa. Through BioInnovate Africa Programme, *icipe* has demonstrated that when deliberate and dedicated support is available, biologically-based innovations, as well as a sustainable bioeconomy, are possible in Africa.

The Programme has become the largest and most active regional science and innovation-driven bioeconomy platform in Africa, with over 1,000 scientists and innovators in more than 200 organisations in eastern Africa as direct beneficiaries. From 2018 – 2022, 25 innovation projects were supported through BioInnovate Africa Programme. Of these, 17 products were successfully tested, validated and launched in the market. Several of the products have entered the venture growth stage. This is a remarkable success rate. Examples of products that have been successfully tested and are gaining market entry include: biofertilisers from agricultural wastes; a seed delivery system for virus-free sweet potato vines; nutrient enriched foods from sorghum and millet; edible insect enriched food; aroma honey toffees; orange fleshed sweet potato puree for bakery products; black soldier fly larvae for chicken feed; mushroom substrate blocks; and an integrated solution for treating industrial wastewater.

Furthermore, during this review period, BioInnovate Africa Programme has supported 50 students (40 Master's and 10 PhDs), in the region and contributed to more than 100 scientific publications. In partnership with Thayer School of Engineering, USA, the Programme is building a techno-economic analysis (TEA) capacity for innovation initiatives in eastern Africa. This is through a course that was jointly established in 2019 to provide develop capacity to assess potential economic feasibilities and bottlenecks, and to identify research and development requirements during early stages of biobased technologies that have real world application in developing country settings. The course is open to students who have enrolled for a Master's or a PhD programme at a university in any of BioInnovate Africa Programme's partnering eastern African countries. Eight students have been trained so far. They have conducted TEA on selected BioInnovate Africa projects.

In 2022, Sida and *icipe* signed a new cooperation agreement for the Centre to implement BioInnovate Africa Programme phase III (2022 – 2027). The Programme will continue to support scientists in universities, research institutes and firms to translate innovative biologically based research outputs into practical uses that address development challenges in the region. The participating countries are Burundi, Ethiopia, Kenya, Rwanda, Tanzania and Uganda; with the Democratic Republic of the Congo (DRC), and South Sudan as new entrants. The four broad project categories aim to: improve food production and food safety; reduce postharvest losses; provide biodegradable alternative packaging materials; and improve human and animal health. The initiatives are aligned to national, regional and global agenda including the recently adopted East African Regional Bioeconomy Strategy. The activities support the United Nations Decade of Action (2020 – 2030), to accelerate the achievement of the Sustainable Development Goals (SDGs); the African Union Agenda 2063; and the targets of the East African Community vision 2050 to boost value addition and agro-processing as the biggest direct employer of all manufacturing industries in the region.

Unfortunately, BioInnovate Africa recently suffered a 58% budget cut from Sida, which led to the downsizing of BioInnovate Africa Programme. As a result, some of the projects were not awarded any funds while those awarded had to be reduced in scope.

6. REGIONAL SCHOLARSHIP AND INNOVATION FUND

In 2013, in response to the critical need to strengthen the scientific and technological capacity of SSA, to promote development and achieve economic transformation, the Partnership for Skills in Applied Sciences, Engineering and Technology (PASET) initiative was launched by the World Bank. A unique aspect of PASET is that it is managed and funded mainly by African governments, and it is also supported by the private sector, development partners and partner countries in Asia, such as South Korea. Initially, PASET was launched by three African countries, but there are now nine African countries actively supporting it.

In 2016, PASET launched its flagship programme, the Regional Scholarship and Innovation Fund (RSIF), with the objective of establishing a pan-African science fund to boost doctoral training in African universities and to strengthen their institutional capacity for undertaking quality, sustainable and innovative research in transformative technologies in Africa in five identified critical thematic areas: climate change; energy, including renewables; food security and agribusiness; ICT, including big data and artificial intelligence; and minerals, mining and material engineering. In 2018, following an international call by the World Bank, *icipe* was competitively selected as the Regional Coordination Unit (RCU) of RSIF. RSIF, however, continues to operate under the PASET governance. The strategy of RSIF is to select brilliant African candidates, many of whom are full-time academics at African universities, and provide them with scholarships to undertake their doctoral training in selected African host universities (AHUs), in collaboration with international partner institutions (IPIs) where the scholars spend up to one year of their studies under a sandwich agreement. At present, there are 15 AHUs in 11 African countries: Benin, Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Kenya, Nigeria, Rwanda, Senegal, Tanzania, and Uganda. The 29 IPIs are in South Korea, Japan, the USA, Europe, Brazil, Israel, Morocco, South Africa and India.

RSIF also awards competitive research and innovation grants to AHUs hosting PhD scholars by supporting research that promotes scientific excellence and use of knowledge for development impact. A total of 41 such grants have been awarded to AHUs in eight countries (23 research grants, and 18 innovation projects). There is equally provision under RSIF to award Junior Investigator Research Award postdoctoral grants to those RSIF scholars who have completed their PhD. Eight of the first 10 students who graduated in 2022 and 2023 and have returned to their home countries have received this award. Through the EU funded AGriDI project, nine digital innovation grants were also awarded. In 2018, the World Bank provided a grant of USD 15 million to *icipe* for running the RCU. Between 2010 – 2022, the RCU at *icipe* has managed RSIF remarkably well, ensuring its progress and demonstrating that the RSIF concept works. At present, RSIF activities are funded through a General Fund to which each African country supporting the initiative contributes about USD 2 million. Currently, the governments of Benin, Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Mozambique, Nigeria, Rwanda and Senegal are investing in RSIF. The South Korean government has also contributed USD 9 million to the Fund. The total funding received for RSIF by July 2023 is USD 56 million, 47% of which has been contributed by African governments, 27% by the World Bank, 16% by Korea, 8% by the European Union and 2% by the Carnegie Corporation of New York.

A total of 291 Rsif PhD scholarships awarded; and 8 out of 15 cohort 1 scholars had completed their studies. Currently, 37 percent (104 scholars) of the 278 active Rsif scholars are women. By 2022, the Rsif scholars had published a total of 122 peer reviewed papers. RSIF funding has resulted in the publication of 166 research papers in international refereed journals as of 31 July 2023. Several innovations have been developed, including Internet of Things devices, a solar heat pump drier for fruits and vegetables, biopesticides for yam fungi and two patents in oil and gas. Another example of RSIF's success is Dr Noel Gahamanyi of Rwanda who graduated from the University of Sokoine in Tanzania in 2021 with the best PhD dissertation award. He has now returned to the University of Rwanda where he currently serves as a resource for his country in molecular epidemiology and antimicrobial resistance. He has been granted an RSIF Junior Investigator Research Award, and was also appointed by the government of Rwanda to head the Microbiology Unit of the Rwanda Biomedical Centre, National Reference Laboratory. For RSIF to be sustainable in the long-term and to meet the medium-term objectives of training PhD scholars and funding research and innovation in African universities, there was a proposal for the establishment of a Permanent or Endowment Fund for RSIF through a pool of permanent capital that would be invested to generate returns to fund RSIF needs. A feasibility study on the establishment of an Endowment Fund was undertaken in 2020 by a consultancy firm, which showed that a significant sum would need to be raised over 20 years to meet the desired outflows of PhD scholars and research grants under RSIF. So far it has not been possible to create such a Fund. One idea being explored by PASET is how to tap green innovative financing through carbon offsets to widen the revenue base of RSIF. The funding of PASET Secretariat by the World Bank ended on 30 June 2023, and its grant to *icipe* to run the RCU of RSIF will end in December 2025, with no prospect of extension. PASET is currently reviewing its funding modalities. Ensuring the long-term financial sustainability of RSIF remains the major challenge facing the programme.

7. GOVERNANCE AND MANAGEMENT

7.1 Governance

The supreme governing body of *icipe* is its Governing Council (GC), established in accordance with the Centre's Charter. The GC, which meets once a year, consists of 15 members with the *icipe* Director General (DG) as an ex-officio member. An Executive Board of the GC provides guidance to the *icipe* senior management in-between GC meetings. Eight of the GC members are drawn from the Sponsoring Group of *icipe* (SGI), which comprises a member representation from countries of the main donors that fund *icipe*. Between 2016 and 2019, under the leadership of Biovision Foundation, there was concerted effort to revive the SGI – its terms of reference were revamped, and various donors were approached to join the grouping. While this process has been slow, there has been momentum with members of the group consulting each other on various matters, while also reaching out to other donors. The Chair of the SGI moved to SDC from 6 November 2020.

The DG is responsible to the GC for the management and operation of *icipe*, ensuring that the Centre's programmes and objectives are properly executed. The DG is assisted by several senior staff: the Director of Finance and Administration (DFA), who supervises all financial and administrative matters; and the Director of Research and Partnerships (DRP), who oversees all the R&D activities. Both Directors report to the DG. In 2022, however, the post of DRP was repurposed temporarily and all the institution's R&D activities came under the direct responsibility of the DG. Recruitment for a replacement was put on hold to await the new DG. Since 2022, therefore, senior leadership has been assumed by just the DG and the DFA. The DG is assisted by a Senior Management Committee (SMC) that includes the DFA, the Heads of the 4Hs Themes, the Head of the Capacity Building and Integrated Sciences, the Head of the Ethiopia Country Office and the Manager, Research Innovation Coordination Units (responsible for BioInnovate Africa and PASET-RSIF programmes). The SMC meets monthly and contributes to Centre management (see Annex 3, Organisational Structure).

A major development is to take place in *icipe* governance by the end of 2023. Both the DG and the DFA will be retiring. A new DG has already been recruited and will assume office on 1 January 2024. The process of recruiting a new DFA is underway. The position is open and will be filled.

7.2 Results Based Management and Enterprise Resource Planning

As all the R&D work at *icipe* is conducted through externally funded projects, in 2011, *icipe* adopted the Results Based Management (RBM) as a project planning and monitoring tool. The RBM is both a management and reporting system. It is a life-cycle approach to management that integrates strategy, people, resources, processes and measurements to improve decision-making, transparency and accountability. It is used by senior management and donors to ensure compliance with acceptable performance and accountability standards and to track achievements. The RBM is aligned to *icipe*'s *Vision and Strategy* (V&S). RBM frameworks were developed for V&S 2013-2020, and V&S 2021-2025. The latter incorporates the recommendations of the last *IPER* 2013-2017. RBM is continuously evolving and is therefore labelled 'rolling' over the specified period; it is updated annually. As with any management tool, the RBM takes time to become fully adopted, and it needs to improve and adapt as it progresses. This applies equally to *icipe*. However, over the last decade, *icipe* has made progress in productively implementing the RBM system.

In 2018, the *IPER* 2013-2017 mentioned plans by *icipe* to introduce an Enterprise Resource Planning (ERP) system which would integrate finance, human resources, grants and travel into an integrated online system. A private company was contracted in 2018 to undertake the entire process of installation – from supply and delivery to training, testing and deployment. A module was operationalised in January 2023, with additional modules gradually deployed during the rest of the year. Implementing an ERP system in an organisation is a complex technical, costly undertaking. This perhaps explains the lengthy duration for the implementation of an ERP at *icipe*. But it is a worthwhile effort: the ERP does offer significant advantages, especially in an organisation like *icipe* which receives numerous grants from donors.

7.3 Procurement

The *icipe* Procurement Unit is centralised at the Duduville campus and is responsible for procurement of goods and services for the entire Centre; its campuses, country offices and field stations. The Unit has a staff of seven and it oversees the entire procurement process, from tendering, selecting suppliers, to ensuring acquisition and delivery. During the period under review, the Unit successfully executed two major processes. First, in 2020, it acquired goods and services for the MOYESH programme with a monthly budget expenditure of some US\$1 million. In 2019, *icipe* received about US\$56 million from Mastercard Foundation for implementing MOYESH in Ethiopia. Second, in 2022 – 2023, the Unit procured several advanced laboratory equipment amounting to about US\$2.5 million through a grant received in 2021 from Sida. As observed by the RT during their visit to the laboratories in the Duduville campus, these items of equipment are the most up-to-date, state of the art and of international standard, and will be a huge asset to *icipe*.

7.4 Impact of Global Events

The COVID-19 pandemic was a major disruption over a significant proportion of this review period (approximately from March 2020 – June 2022). The RT understands that *icipe* remained fully open and operational at Centre level, with the management and staff being physically present every working day during that period to sustain productivity. This was possible because of protocols developed early on, and the vaccination of staff, students and partners in the collaboration of government authorities. We were also informed that there was no loss of life of any *icipe* staff as a result of COVID-19, which is a credit to the organisation. However, invariably the COVID-19 pandemic must have affected the progress of research projects, especially those necessitating field work. Some of the donors in fact agreed to provide no-cost extensions of about one year to their projects. All the meetings of the GC and its Executive Board were conducted virtually.

Another noteworthy global event during the period under review was the war in Ukraine that started in February 2022, which continues at the time of writing this report. That event, too, has had an indirect impact on *icipe*'s R&D activities due to reprioritization among several governments and major funding agencies and consequent rechanneling of resources.

7.5 Campuses and Infrastructure

icipe has two campuses: the Duduville Campus in Nairobi, the Centre's headquarters since 1990; and the *icipe* Thomas Odhiambo Campus (iTOC) at Mbita Point, western Kenya on shores of Lake Victoria, which was inaugurated in 1986. The *icipe* Duduville Campus consists of state-of-the-art laboratories, including the African Reference Laboratory for Bee Health, which is designated as a collaborating centre by the World Organization for Animal Health (WOAH), and the Martin Lüscher Emerging Infectious Diseases (ML-EID) laboratory; the spacious Thomas Odhiambo Conference Centre that hosts numerous fora; an information resource centre; offices; and an International Guest House. As of 2022, about 56.5% of *icipe*'s total 533 staff were based at the Duduville Campus.

Access to iTOC from Nairobi is usually by air to the airport in Kisumu City, and then a 180 km road drive to Mbita Point. On approaching iTOC, as one goes through Homa Bay County, one sees the purple flowers of the *Striga* weed in the maize fields on either side of the road – a beautiful sight for the visitor, but a nightmare for the smallholder farmers. This is somewhat paradoxical as it was at iTOC where, some 30 years ago, *icipe* launched its flagship push-pull technology to free maize from the *Striga* weed.

iTOC has laboratories and offices, experimental and demonstration fields, insectaries and animal rearing facilities. It also has conference and teaching facilities. Currently, there are some 112 staff working at the Campus. There is a Guest House as well as residential facilities on the campus, comprising 12 maisonettes, 20 flats and student residences. St Jude's outpatient clinic, which was open to *icipe* staff and their families, as well as the community living adjacent to the campus, used to be located at the iTOC, and was the only facility in the area providing quality health care, including access to qualified doctors and dental services. However, the clinic was closed in November 2019 due to multiple logistical, financial and operational reasons³. There is also a public school located at iTOC.

Both campuses host several national, regional and international R&D organisations. There are six at the Duduville Campus: International Institute for Tropical Agriculture (IITA), BioVision Africa Trust, the African Centre for Technological Studies (ACTS), Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT), the International Fertilizer Development Center (IFDC) and the Partnership for Economic Policy (PEP). The four at the iTOC are Nagasaki University, Japan International Cooperation Agency (JICA), World Agroforestry Centre (ICRAF) and the Kenya Medical Research Institute (KEMRI). The hosting arrangement is beneficial to each campus as it creates opportunities for collaboration and attracts regional and international visitors. The hosted organisations also cost-share the overheads of running the campuses.

icipe has two **field stations** in Kenya. The Muhaka field station, located in Kwale County, South Coast, has three laboratories and an office. The main activities at the station during this review period included the Plant Health Theme, aiming to upscale the fruit fly IPM packages (2015 – 2021). Currently, the Human Health Theme is working with the community to seek solutions for NTDs such as tungiasis, and to test a One Health model for animal and human diseases. These technologies, if adopted, can change the lives of those communities. The Animal Health Theme is continuing longstanding research (including surveillance of early response and prevention), dissemination and upscaling of the

³ The information about St Jude's clinic has been obtained from *icipe*'s website on 18 August 2023 which, however, does not mention that it has been closed since 2019.

tsetse fly control tools (repellent collars and traps). In addition, the team has tested a breakthrough strategy using a novel biopesticides, for the control of ticks in livestock.

icipe's second field station is in Nguruman, Kajiado County, in southern Kenya, close to the border with Tanzania. The facility has one laboratory, and a guest house. It is solar-powered, supplemented by a generator. For long, Nguruman, has supported animal health research; the *icipe* Ngu trap was developed and tested there (hence its name). During this review period, the station was a base for studies on NTDs, primarily leishmaniasis, and arboviruses transmitted by mosquitoes, sand flies and ticks. Since the station is close to the Nguruman Escarpment it has been used for plant health activities, and it is ideal for integrated One Health systemic studies.

There have been several changes in *icipe* **country offices** over this review period. *icipe* now has three country offices: in Ethiopia, Uganda and Benin. Hosted at the International Livestock Research Institute (ILRI) campus in Addis Ababa, the Ethiopia country office is the largest and most active. *icipe* started its operations in the country in 1993, and over two decades, the Centre implemented successful programmes on tsetse management, malaria control and beekeeping. In 2016, the Centre re-structured its Ethiopia presence, with an effective strategy that included the appointment of a Country Head and other essential positions, using core funds. This shift positioned the Office for further investments by various donors including the Mastercard Foundation, USAID, Biovision Foundation and SDC. During this review period the *icipe* Ethiopia Office led eight projects, including the YESH and MOYESH initiatives; and it collaborated with the Centre's researchers on four more. In particular, the launch of the MOYESH project led to the recruitment of many staff, and a major expansion of the Office. Currently, the *icipe* Ethiopia Office has about 100 staff and several PhD students. About 50% of the staff are based in field sites across the country. Several of the organisational functions such as financial, procurement and human resources are undertaken in Ethiopia with support and directional guidance from the *icipe* headquarters. Initially, human resources management was being supported by ILRI, but with the large number of staff to be recruited under the MOYESH project, in 2020, this function was assumed by *icipe*.

The *icipe* Uganda country office was opened in 2012, based in Tororo, eastern Uganda, with the mandate of disseminating the push-pull technology, with the support from the programme team based at the iTOC. The Office is now located in Jinja town. Over this period, working closely with the Technology Transfer Unit (TTU), the office supported push-pull activities, helping to conduct validation trials in Zambia, Malawi and Rwanda. The Office has also been instrumental in the implementation of the Community Based Fall Armyworm Monitoring and Early Warning (CBFAMFEW), an *icipe*-FAO initiative aiming at building capacity among community to scout pheromone traps using mobile applications in Rwanda, Burundi and Uganda.

The Benin country office was established in 2019/2020 and is *icipe*'s only office in Francophone West Africa. It is hosted at the IITA campus. The office is implementing the 'Accelerating Inclusive Green Growth Through Agri-based Digital Innovation in West Africa' (AgriDI) project, with a grant from the Innovation Fund of the Organization of African, Caribbean and Pacific States (OACPS), funded by the European Union. The project, which was designed by RSIF and BioInnovate, makes competitive sub-awards for agri-based digital innovation projects in West Africa. The Project Manager and Finance Officer of AgriDI are based in Benin, where three of the AgriDI projects are being undertaken.

In 2014, with funding from the Swiss Agency for Development and Cooperation (SDC), the Centre embarked on the **Greening of *icipe*** initiative that implemented energy saving measures, solar energy measures and water conservation. The main components of the project, which were completed in December 2019, comprised installation of photovoltaic solar panels to reduce energy consumption from the national electricity grid and the fuel-powered generators, thus increasing clean energy usage. Energy saving was achieved through upgrade of the electric systems, while the water conservation was realised through investment in water harvesting, upgrade of piping systems and installation of smart taps. These measures were applied across the Centre's establishments: the two campuses (Duduville and iTOC), and the two field stations (Muhaka and Nguruman). The end results were remarkable. In 2022, data showed that *icipe*'s total energy consumption had reduced by about half from its value in 2014, with solar energy contributing 32% of the total energy consumed. The water consumption at Duduville campus dropped by about 28%, with rainwater harvesting contributing 1% of total consumption. At iTOC, the project enabled the use of clean but unchlorinated water to irrigate the experimental crop fields, thus reducing the use of chlorine and ground contamination. *icipe* should be commended for having embarked on such an initiative. These efforts have been supported by environmental regeneration and conservation measures, which reduce the Centre's carbon footprint, while also creating a thriving, eco-friendly landscape that has numerous flora, insects and bird species.

As indicated in the sections above, in general, *icipe* has modern research facilities and well-equipped laboratories. During this period, the Centre embarked on **infrastructural upgrading and renovation**. This includes the iTOC as well as Muhaka and Nguruman field stations. The RT stayed in both and found the facilities and services to be excellent. The Centre's scientific infrastructure has also been upgraded. This includes a long overdue refurbishing and modernisation of the R&D complex at the *icipe* Duduville Campus, to bring to it world-class laboratory best practices. Various laboratories have also been re-equipped with state-of-the art equipment, including the Behavioural and Chemical Ecology Unit, Molecular Biology and Bioinformatics Unit and the Biosystematics Unit. Across the Centre, numerous upgrades have been implemented including the IT infrastructure, conferencing facilities and the workshop, to mention a few.

8. RESOURCE MOBILISATION AND FINANCE MANAGEMENT

8.1 Resource Mobilisation

The period under review was marked by global turbulences, particularly the second half, with the emergence of COVID-19 pandemic, which shifted priorities in most countries around the world. This period also coincided with an increase of populism leading to drastic reprioritisation of funding from several organisations, especially governmental donors from the United Kingdom, the United States and European countries. Further, the considerable critique that surrounded the reorganisation of the CGIAR system intensified scrutiny of public agricultural research and resource allocations, especially to organisations in developing countries.

In the face of these challenging external forces, it is impressive to note *icipe's* remarkable resilience, pre- and post-COVID-19 pandemic period, and the Centre's current strong financial position. As a key contributor to most of the United Nations Sustainable Development Goals (SDGs), including those targeting climate change; and the African Union Agenda 2063, *icipe* has established strong partnerships with a variety of governmental and non-governmental donors across the globe. Indeed, donor engagement is one of the top responsibilities of the Centre's Management. Jointly, the *icipe* Management, scientists, Grant Management and Resource Mobilisation offices, have built strong relationships with funders. *icipe* is also very adept in aligning the Centre's mission and vision to the objectives of donor agencies.

icipe is funded by an impressive spectrum of donor organisations. During this review period, the Centre welcomed 39 new donors during this review period (*see Table 4). *icipe's* donors range from national governments in Africa, Australia, the EU countries especially Sweden and Germany; Switzerland and Norway; Canada; and the United States of America; private philanthropic organisations such as the Bill & Melinda Gates Foundation, Open Philanthropy, The Rockefeller Foundation, IKEA Foundation, Children's Investment Fund Foundation, Wellcome, Novo Nordisk Foundation, Gordon & Betty Moore Foundation, The Curt Bergfors Foundation Food Planet Prize, Bertha Foundation, Mozilla Foundation and L'Oréal Corporate Foundation. Most of the donors provide funds for specific projects, in accordance with their own priorities and those of *icipe*. During this review period, *icipe* received over USD 170 million in funding for its programmes, amounting to an average funding of approximately USD 34 million per year (*see Table 5: Top donors and their contributions: 2018 – 2022).

Several of the donors provide unrestricted core funding. *icipe* obtained a USD10 million core funding commitment over the 5-year period ending in 2027. As of October 2023, *icipe's* core donors are: Swedish International Development Cooperation Agency (Sida); Swiss Agency for Development and Cooperation (SDC); the Australian Centre for International Agricultural Research (ACIAR); Norwegian Agency for Development Cooperation the Federal Democratic Republic of Ethiopia; and the Government of the Republic of Kenya.

icipe has managed to raise funding for innovative R&D activities across the 4Hs themes (Human, Animal, Plant, and Environmental Health); special programmes such as the insects for food and feed and other uses; designated One Health initiatives; and most commendably, for infrastructure upgrades like re-equipping of scientific laboratories. A sizeable amount of these resources are directed to basic research, but it is noticeable that most of the funding is expected to enhance the adoption of technologies, with demonstratable impact on the ground.

Two major funding opportunities stand out during this review period. The first is the competitive selection of *icipe* to host RSIF, in 2018. In that year alone, *icipe* received a grant of USD 24 million for the management of RSIF. Subsequently, *icipe* has benefited significantly from the grants received for the RSIF programme throughout this period and continues. These resources have boosted *icipe's* capacity building efforts, and, overall the Centre. The second major grant (USD 56 million), the largest project grant ever received by *icipe*, was awarded in 2019 by the Mastercard Foundation for the MOYESH project (Environmental Health Theme). Indeed, *icipe* has been notably successful in its partnership with the Mastercard Foundation. Interestingly, after the Environmental Health Theme, the Plant Health Theme has received the largest number of grants, indicating a higher level of donor interest in this area where *icipe* happens to be strongest. The Human Health Theme has received support from organisations that are funding malaria control such as the Bill & Melinda Gates Foundation and Wellcome. On the other hand, it is noteworthy that *icipe's* CBID programme received only USD 0.5 million over the review period, by far the lowest than any other programmes. Some of the top donors for the year 2022 and their significant contributions are listed in the Table 4 below.

Table 4: 39 new funders (2018 – 2022)

1.	Australian Centre for International Agricultural Research (ACIAR)
2.	Bertha Foundation
3.	Bill & Melinda Gates Foundation
4.	Cambridge-Africa ALBORADA Research Fund 2019
5.	Canadian Executive Service Organization (CESO-SACO)
6.	Chalmers University of Technology, Sweden
7.	Children's Investment Fund Foundation (CIFF)
8.	Code for Science & Society
9.	Deutsches Zentrum für Luft- und Raumfahrt - German Aerospace Center (DLR)
10.	Elsevier
11.	Ethiopian Catholic Church Social Development Commission (ECC-SDCBOM)
12.	Farmtrack Consulting Limited
13.	Federal Democratic Republic of Ethiopia
14.	Federal Republic of Nigeria
15.	Future Leaders – African Independent Research (FLAIR) Fellowships 2019 Round 1
16.	Government of Kenya, through the National Research Fund – Multi disciplinary Research Grant
17.	Government of South Korea
18.	IKEA Foundation
19.	IMPAXIO GmbH, Zürich, Switzerland
20.	Max-Planck Institute for Chemical Ecology, Germany
21.	Ministry for Primary Industries (MPI), New Zealand
22.	Mozilla Foundation

23.	Netherlands Postcode Lottery led by Stichting Cordaid
24.	Norwegian Agency for Development Cooperation (Norad)
25.	Norwegian Refugee Council (NRC)
26.	Novo Nordisk Foundation, Denmark led by Impact Designs
27.	Open Philanthropy
28.	Participatory Ecological Land Use Management (PELUM) – Kenya
29.	Remote Sensing Solutions (RSS) GmbH, Germany
30.	Republic of Benin
31.	Republic of Burkina Faso
32.	Republic of Côte d'Ivoire
33.	Republic of Ghana
34.	Republic of Mozambique
35.	Republic of Rwanda
36.	Republic of Senegal
37.	The Curt Bergfors Foundation Food Planet Prize (2020)
38.	University of Eastern Finland
39.	World Bank

Table 5: Top donors and their contributions (2018 – 2022)

DONOR NAME	Purpose	Amount in USD "000"
Mastercard Foundation	Job creation for the youth through apiculture and sericulture value chains	36,582
Swedish International Development Cooperation Agency	Strategic long-term funding and BioInnovate Africa Programme	24,968

DONOR NAME	Purpose	Amount in USD "000"
World Bank/Korea Government/African Governments	Regional Scholarship and Innovation Fund (RSIF)	15,138
European Union	Integrated pest management, Agri based digital innovation	13,151
Swiss Agency for Development and Cooperation	Strategic long-term funding	10,506
Foreign, Commonwealth and Development Office	Strategic long-term funding	6,726
Biovision Foundation for Ecological Development	Multiple projects in the 4Hs (Plant, Human, Animal and Environmental health)	6,143
Germany Agency For International Cooperation/German Federal Ministry for Economic Cooperation and Development	Animal Health, integrated pest management	5,542
Norwegian Agency for Development Cooperation	One Health	3,383
International Development Research Centre	Insects for food and feed and other uses	2,346

8.2 Views of Donors

The RT engaged in direct discussions with several key donor representatives. The donor groups were quite pleased with their choice of grantee and consistently commented on the timely delivery, high quality and consistency of *icipe* reports. According to one donor, *icipe* 'consistently over-delivered and exceeded the goals'. Indeed, it was partly due to *icipe*'s diligent project and financial management that the Centre was entrusted with the management of RSIF during the current review period. The donors complimented *icipe* on their efforts in adhering to the budgets, addressing the capacity building goals, and focus on projects that enhanced youth employment in Africa, as in the case of the MOYESH project in Ethiopia. However, the donors interviewed wanted to ensure that *icipe* implements and maintains strong internal control measures that align with the organisational processes and mandate. As mentioned above, one of the key issues that arose related to core funding, a key priority for the *icipe* management team.

Overall, *icipe* is a 'favourite' of the donor groups and they were unanimous in their consensus on how well the organisation is managed. However, there were several concerns: (i) impending senior management changes and their potential implications on the activities, programme overload causing delays in responsiveness to donor requests; (ii) budget cuts in donor organisations due to changing country priorities resulting in reduction in grants; (iii) need for a more carbon-neutral travel policy.

The donors also emphasised the importance and need of strengthening the Sponsoring Group of *icipe* (SGI) of the Governing Council to ensure funding of the Centre's core activities. They also expressed varying degrees of concerns about the overall shifts in the funding landscape associated with global conflicts; policy shifts in donor countries; anticipated changes in leadership as well as senior management at *icipe*; prevailing recruitment challenges including compensation for senior international staff at Africa-based institutions; as well as aligning the Results Based Management Framework with the institutional objectives. With the growth and expansion at *icipe*, there may be a need for the organisation to address the specific concerns relating to the management of grants through direct engagement with donors. The RT did not have opportunity to engage with many donors; but in the limited review some of the concerns mentioned include speed of response to specific requests for information the SGI group is expected to convene and

review some of these topics during their upcoming meeting. Several of these concerns are reflected in our recommendations.

8.3 Finance

The Finance and Administration Unit at the *icipe* headquarters oversees the overall management of the finances, including planning, budgeting, accounting, financial reporting as well as the treasury and risk management procedures of *icipe*. The Unit is headed by a Director of Finance and Administration (DFA) with direct accountability to the DG. The DFA reports periodically to the GC and has diligently submitted annual audited financial statements which were all available to the RT for consultation. He is supported by an excellent team of support staff. The Internal Auditor reports directly to the DG and the Governing Council (see Annex 3).

There was substantial increase in the Centre's total assets during the review period from USD 50 million to USD 70 million; however, the total assets, less total liabilities, increased only modestly from USD 22.24 million in 2018 to USD 24.79 million in 2022. *icipe*'s total income also increased from USD 25.07 million in 2018 to USD 39.34 million in 2022. The total reserves and funds of the Centre have remained relatively constant with minor fluctuations during the review period from USD 24.14 million in 2018 to USD 24.79 million in 2022.

8.4 Unrestricted Core Funding

Despite this steady inflow of new and significant grants to *icipe*, it is important to point out that a review of the documentation revealed a steady trend towards a reduction in core funding as a percentage of the total income, as well as a reduction in the total amount (see Table 5). Over the previous review period, the percentage values had decreased from 25% in 2013 to 18% in 2016.

Table 6: Unrestricted Core and Restricted Project Grants Received by *icipe* over 2017-2022

US\$ 000	2017	2018	2019	2020	2021	2022
Unrestricted Core Grants	4,238	4,544	4,320	4,977	3,591	2,466
Restricted Project Grants	15,623	17,960	24,959	25,128	32,150	33,401
Other Incomes	2,488	2,571	2,441	2,107	2,164	3,473
Total Income	22,349	25,075	31,720	32,212	37,906	39,341
% Core Grant	18.9	18.1	13.6	15.5	9.5	6.3

This trend is consistent with a global trend towards minimal contribution towards core or unrestricted funding among the donor community. The *icipe* team is cognisant of this trend at other organisations and has been applying cost recovery to its existing projects to supplement its core funds. However, this is not yielding the desired results. Over the review period, the cost recovery from restricted research grants varied between 9 –11% of the grants each year, whereas the desired target was 20-30%. Despite this, *icipe* has worked at recovering the deficit.

An alternate approach to address this issue is for *icipe* to implement a cost-recovery method for its projects whereby the entire cost of implementing the project is secured from the donor prior to the recognition of the revenue by the organisation. Though more cumbersome to operate, considering the high-efficiency approach at *icipe* administration, *icipe* is considering such a model to help address the issue of managing the overhead costs associated with its projects, while addressing donor requirements.

The need for more core funding was also raised during the RT's discussions with members of the donor community, some of whom (e.g. ACIAR, NORAD, SIDA) have indicated their intention to provide more core funds in the coming years. While this is definitely encouraging, *icipe* needs to continue to pay attention to this aspect which will affect its core activities.

9. OPERATIONALISATION OF THE VISION AND STRATEGY 2021-2025

One of the terms of reference of the RT and this IPER, is to examine *icipe's* success in operationalising its *Vision and Strategy 2021 – 2025* (V&S 21-25). Since this review is for the period 2018 – 2022, it means that there is an overlap with the *Vision and Strategy 2013 – 2020* (V&S 13-20). Thus, in this section we will consider *icipe's* progress in view of these two strategies.

- The first strategy of V&S 13-20 was the expansion of *icipe's* research focus towards the **One Health concept**. This also appears in V&S 21-25. As deliberated in the sections above, *icipe* is fully conscious of the importance of the One Health concept and has taken steps to operationalise it.
- Improvement in the **adoption of technologies** was the second strategy of V&S 13-20. The document mentioned that *icipe* would expand its capacity building programmes to include public and private extension agents and agencies, especially towards more direct training of farmers and rural communities, with special emphasis on building effective public-private partnerships as the core means to deliver impact. V&S 21-25 indicates a similar strategy but frames it as greater support for the **uptake of *icipe's* research**, especially by implementing the Centre's projects through participatory action research (PAR). Between 2018 – 2022, *icipe* conducted the capacity building of a range of stakeholders, including farmers and extension workers, mainly through the Centre's Technology Transfer Unit. *icipe* has also been very successful in establishing partnerships with the private sector to commercialise its technologies. One good example of public sector partnerships is *icipe's* close collaboration with the Kenya Plant Health Inspectorate Service (KEPHIS) to introduce natural enemies of major invasive species (for example fruit flies, fall armyworm and the tomato leaf miner), which are threatening smallholder agricultural productivity in the country. These natural enemies have resulted in significant economic impacts (Macharia et al., 2005; Mukiri et al., 2020; Mulungu et al., 2023; Mohamed et al., 2022; Githiomi et al., 2019; Midingoyi et al. 2023). The Centre has also partnered with a range of public sector organisations, NARs, farmers and community-based organisations to mass produce and augment the natural enemies. Such efforts need to be further supported and scaled-up by the national governments and institutions to extend reach of *icipe* interventions to millions of smallholder farmers.

The INSEFF programme is another example where *icipe* has established a strong network of partnerships and collaborations with public-private sector actors. These include organisations such as Kenya Marine and Fisheries Research Institute (KMFRRI), Kenya Agricultural and Livestock Research Organization (KALRO), and Jomo Kenyatta University of Agriculture and Technology (JKUAT), University of Nairobi, Kenya Bureau of Standards (KEBS) all in Kenya; Uganda National Bureau of Standards (UNBS) and Makerere University in Uganda; Rwanda Agricultural Board (RAB), Rwanda Standards Board (RSB) and University of Rwanda; Institute of Ethiopian Standards (IES) and Ethiopia Agriculture Authority; African Organisation for Standardisation (ARSO); and a large suit of private-sector partners, including Regen Organics, Zhihanga farms, Insectipro, Insectary Ltd., Protein Masters, Zhi among others. For instance, *icipe's* close interaction with KEBS, UNBS, RSB and IES and other partners led to the establishment of regulatory frameworks for integration for the insect-based sector in Kenya, Uganda, Rwanda and Ethiopia. These milestone achievements triggered vast investments by start-up companies and small- and medium-scale enterprises to engage in farming edible insects for feed and fertiliser sector.

The YESH and MOYESH projects have increased the number and diversity of partners collaborating with *icipe*. These partners include various agencies along the honey and silk value chains, embracing government, non-government, financial institutions, private sectors, and communities. The initiatives have also created new experiences in implementing large scale grants, and its target of over 100,000 beneficiaries has enabled us to increase *icipe's* implementation capacity. They have also provided insights into novel development models, for example, the value chain approach and socio-economic information on behaviour change of partners, as well as aspects like social capital and knowledge capital.

Engaging with public and private sector partners, particularly the NARS and government agencies especially in the early stages of developing programmes, is an area that *icipe* can continue to develop further. This is a work in progress – the Centre continues its support for the uptake of its research using a participatory action research (PAR) paradigm for stronger engagement with national and regional innovation system actors to achieve its impact.

- V&S 21-25 also mentions the establishment of a **Biocontrol Consortium** of private sector and other stakeholders to fast-track commercialisation of *icipe's* products. The Centre is making progress towards forming the Consortium, which will also provide advice on research and capacity building priorities; and act as a conduit for national and regional policy and regulatory agencies.
- Another proposed strategy in V&S 13-20 was to recruit additional **personnel in social sciences and development** to enable the Centre to better understand the constraints to adoption and to have better estimates of the social and economic benefits of programmes. Since 2017, *icipe* has fortified the SSIA Unit, allowing better estimates of the social, economic, and environmental outcomes of the Centre's interventions. *icipe* acknowledges the need for additional personnel in agribusiness, machine learning, and bioeconomic modelling to amplify adoption of technologies and impact analysis capabilities.

- V&S 21-25 states that *icipe* will focus on supporting the establishment of better surveillance, forecasting and early warning systems of **invasive insect species** and help to develop national and regional policies to reduce the risks of invasives. In February 2018, *icipe*, CABI and IITA organised a major forum, which led to the development of a Strategy for Managing Invasive Insects (2021-2030). The document aims to create a systematic, coordinated, consolidated, proactive and rapid response, based on a clear contingency plan, supported by enforceable policies, reference points, and an inventory of management options. Furthermore, as discussed in various sections of this report, during this review period *icipe* has generated knowledge and developed inclusive, innovative interventions for a range of invasive species among them fruit fly species like *B. dorsalis*; potato cyst nematodes (PCN); invasive weeds such as *P. hysterophorus*; the devastating tomato leaf miner, *P. absoluta*; and fall armyworm (*S. frugiperda*). Also, the DMMG Unit has made noteworthy contribution in modelling and geo-information, to mitigate invasive species, including the desert locust outbreak in eastern Africa which started in 2019, while developing preventive measures to control future such disasters.
- V&S 21-25 expressed concern about **insect biodiversity loss** as a result of climate and landscape changes and mentions that *icipe* will prioritise research towards identifying such loss. Under its Environmental Health Theme, *icipe* has been studying the drivers and risks associated with pollinator decline in diverse global regions, including Africa. In addition, the *icipe* Biosystemics Unit, which has insect biodiversity and conservation as its mandate, has established a database of 65,000 species of insects in Kenya. However, the Unit needs to extend its work to other geographical regions of Africa. It also could sensitise the population on the harmful effects of biodiversity loss of insects.
- Regarding advancing **microbiome research**, mentioned in V&S 21-25, *icipe* has aimed to find strategic entry points to reduce disease transmission, control crop pests and increase gut microbiome health in chickens and other animals, thus reducing the use of antibiotics in feed supplements. For example, *icipe* researchers found that black soldier fly-based meals increase beneficial bacteria in the gut of poultry, thus promoting their health and growth and minimising antimicrobial resistance. Microbiome research is also being directed towards improving the effectiveness and productivity of beneficial species such as bees. Additionally, *icipe* researchers have been assessing community-level shifts in soil and rhizosphere microbiomes in various agroecological systems to boost soil resilience and develop mitigation strategies using novel amendments for soil and plant health in relation to changing climates.
- Expanding the research agenda to study and promote soil health is another strategy in V&S 21-25. *icipe* takes a nature-positive, One Health, systems-approach to soil health, by promoting regenerative agricultural practices that protect soils from harmful chemicals and synthetic products. The Centre is also producing knowledge on soil ecosystems. The impact of soil biota on plant health is one of the most unexplored frontiers associated with soils. *icipe* is leveraging its strengths in chemical ecology and microbial ecology to boost its soil health agenda. In addition, *icipe* has an extensive research programme on below the ground pests, including plant-parasitic nematodes. Nematology capacity is limited in Africa and *icipe*, jointly with IITA, is promoting capacity and awareness in nematology in SSA. Soil health is an area that requires further development at *icipe*.
- The expectation of V&S 21-25 was that the **PASET-RSIF** programme would be a major growth incentive for *icipe* by providing an entry point to West, Central and Southern Africa. RSIF, as a capacity building, research and innovation programme, has expanded significantly and has been highly successful in enrolling doctoral students and in providing grants for research and innovation. RSIF and the BioInnovate Africa Programme have seized the opportunity to set up an office in Benin, West Africa, to run a project on digital innovation in agriculture. Currently, the activities of the Office are specific to RSIF and BioInnovate, with limited impact on the expansion of the *icipe* 4Hs Themes in West Africa.
- V&S 21-25 mentions that *icipe* will investigate how **emerging genetic technologies** such as CRISPR-Cas9 can be exploited through gene editing approaches to potentially block the transmission of vector-borne diseases to improve African livelihoods by decreasing the human disease burden and increasing agricultural productivity. Realising the lack of expertise in such technologies in Africa, *icipe* held training workshops in 2017 and 2019. *icipe* needs to deepen its investigation in collaboration with partners experienced in these new technologies.

10. CHALLENGES AND OPPORTUNITIES: COMMENTS, SUGGESTIONS AND RECOMMENDATIONS

In this section, we summarise our learnings based on our extensive literature review and visits, as well as our meetings and conversations with a wide range of *icipe*'s staff, beneficiaries, donors and other stakeholders. We identify some challenges, not only those already encountered but also those that could arise in the future. Many of *icipe*'s challenges arise from the fact that the Centre is almost entirely dependent on donor grants. We also point out opportunities, provide our comments and, where relevant and appropriate, offer suggestions and propose recommendations.

10.1 SWOT Analysis of *icipe*

In 2020, in preparation of its V&S 2021-2025, a SWOT Analysis of *icipe* was conducted in collaboration with *icipe* senior management and scientists (see Annex 4). We found the analysis very pertinent as it corroborates with several of our findings.

Among its **Strengths**, the Analysis mentions that *icipe* has a history of delivering on research projects outputs that are valued, and it has developed trusted and strong relationships with several major donors and operates in 42 countries. Among *icipe*'s **Weaknesses** are vulnerability to changes in the current relatively small leadership team, challenges in sustaining the funding streams, especially in accessing core funds, and technology transfer. The identified **Opportunities** include Africa having the fastest population growth becoming the home to the largest and youngest population by 2050, the potential to lead regional and global climate change research, and establishing partnerships with universities inside and outside Africa. The **Threats** identified are changes in priorities and policies introduced by major donors which can negatively impact funding, especially core funding, the problematic loss of key senior research staff and institutional leadership and the difficulties in attracting top scientific talent, lack of inertia in moving beyond the current portfolio of 4-Health research, and the challenge in systems, capacity and leadership in moving beyond East Africa. This SWOT Analysis would be extremely useful to the new leadership team of *icipe*.

10.2 Change in Senior Leadership Team

Until recently, senior leadership at *icipe* comprised the DG and two Directors, one responsible for Finance and Administration (DFA) and the other for Research and Partnerships (DRP). In 2022, the DRP moved to the position of Head of Capacity Building and Integrated Sciences, with the DG taking over the responsibility of supervising the Four Health Themes.

The position of DRP was not filled in 2022. In 2018, senior management agreed with the IPER 2013-2017 recommendation that the small team of only three people in senior leadership positions placed extreme pressure on their time and was not sustainable. The reduction of senior leadership to only two people must have considerably worsened the situation.

Both the DG and the DFA would be retiring by the end of 2023, at almost the same time. We have learnt that a new DG has been appointed and will assume duty on 1st January 2024. We have also been assured that the new DFA would have been appointed by the time the incumbent leaves.

The decision of whether or not to recruit a DRP has been left to the new incoming senior management team. If the new team decides to maintain the same governance structure as before, we would **suggest** that a new DRP be recruited. Another possibility, one evoked in the SWOT Analysis and our preferred option, is that a more devolved governance system be adopted, with leadership shared with the Heads of the Four Health Themes.

10.3 Future Funding Challenge and Resource Mobilisation

Over the review period, there has been a noticeable increase in project funding, which is commendable. The increase has resulted from two main sources: the RSIF programme in 2018 with funding from African governments, and the MOYESH programme in 2019 funded by Mastercard Foundation with all activities undertaken in Ethiopia. Whether such opportunities will arise over the next five years is difficult to predict. Also, because of the aftermath of COVID-19, the war in Ukraine, the increasing drift towards populism and its influence on governments in Western countries, etc. the threat of reduced donor funding in the future exists. The recent reduction in Sida funding to *icipe* and the curtailment of scholarships provided by DAAD are clear indicators. *icipe* needs to be prepared for such eventualities.

In addition to the laudable efforts made by senior management towards resource mobilisation, *icipe*'s Resource Mobilisation Unit has played an equally active role in alerting *icipe* researchers to funding opportunities. It currently only uses the digital Research Beeline tool, which is based in Kenya, is affordable, and is essentially designed for African researchers. There are other more comprehensive digital tools that cover a much wider landscape of research grants internationally, but which are costly.

While applauding the excellent efforts in resource mobilization made by *icipe* over the review period, we **recommend** as follows:

- a) To continue the expansion of the donor base to also include donors and funding agencies from Africa.
- b) To reactivate the Sponsoring Group of *icipe* (SGI) which operates under the GC. The group should perhaps be enlarged to include other *icipe* donors as well. The issue of core funding for *icipe* should be high on the SGI's agenda.
- c) To provide more resources to the Resource Mobilisation Unit to enable it to access additional digital tools for searching availability of research grants internationally.

10.4 Adoption of *icipe* Technologies in Rural Areas in Kenya

icipe has done exceedingly well in developing technologies that help to solve the prevailing constraints in crop and livestock production. One of the key achievements is the use of push-pull technology which suppresses and eventually eradicates *Striga* weed, a great menace in Nyanza and western regions of Kenya where it can cause up to 100% yield losses. Although this technology was initially constrained by a lack of *Desmodium* seeds, *icipe* responded by developing a seed system and currently the seeds are readily available, albeit at relatively high cost. Farmers were also encouraged to use splits to reduce costs by establishing small nurseries of *Desmodium*, then expanding them to get adequate planting materials. We acknowledge that the involvement of partners has helped in increasing the adoption of push-pull technology beyond the *icipe* recorded beneficiaries. However, in western Kenya, it is surprising to still find a farm full of *Striga* and exhibiting a very stunted crop, next to one using push-pull technology, and which is clean of *Striga* and has a robust crop.

Other very good technologies aimed at addressing rural community health challenges, such as tungiasis (jiggers), meet similar adoption constraints. For example, *icipe* has demonstrated that an improved floor in a house reduces tungiasis almost totally, which is greatly appreciated by the beneficiaries. Yet, within the same household, a beneficiary full of praises of the technology is still reluctant to apply that technology to his other houses. Another example is the use of repellent collars on cattle to push away tsetse flies as well as traps to attract the flies, thus leading to an effective control of tsetse flies. The beneficiaries of the technology indicate that they have competing needs and cannot buy the repellent which has to be replenished every six weeks or so at a cost of about USD 2.1.

These examples of limited adoption of *icipe*'s excellent technologies among the rural communities are of concern and there is a need to study the barriers to adoption e.g., whether they are of a sociological or economic nature, and also to enhance engagements with bodies such as County governments in Kenya for ownership, as in the case of Ethiopia under the MOYESH project.

Our **recommendations** to *icipe* are as follows:

- a) Undertake a study, through the SSIA and the TT Units, to establish the causes hindering adoption of *icipe* technologies in Kenya e.g. the persistence of *Striga* weed in the case of PPT or the use of repellents for the tsetse flies.
- b) Make more concerted efforts to engage County governments in Kenya, through the Council of Governors, in implementing projects in rural areas.
- c) Provide opportunities to relevant authorities in Kenya to visit the technology sites to enable them to understand these technologies and appreciate their impact.
- d) Strengthen linkages with multiplier organisations such as NGOs, media and the National Plant Protection Organisation of Kenya for direct transmission of technologies at local level.
- e) In order to stimulate demand for improved technologies, develop a web-mobile application for information on *icipe*'s innovations and technologies to create a direct interaction between research users and promoters involved in technology generation or transfer.

10.5 Using Climate Change as a One Health Concept

icipe is making great effort to implement the One Health concept, despite several hurdles such as lack of funding for One Health research, the preference among researchers for their own specialised field, inadequate human capacity, competition among donors for limited resources, etc. Climate Change, in particular rising temperatures, increase in atmospheric carbon dioxide and vagaries in rainfall patterns and drought, directly impacts on the 4Hs research focus. The phenomenon has a direct impact on the physiology of insects, accelerating their growth, consumption and metabolism, eventually increasing their impact on crop, human and animal health and biodiversity in general. Climate change also could influence the spread of insect populations to new geographical regions. On the flip side, climate change and global warming offers an opportunity to link the 4Hs. Through its various R4D activities *icipe* have

successfully demonstrated the impact of climate change on insects' biology, ecology, potential for expansion (e.g. predictions on invasive species such as fall armyworm with climate change), spread, damage including disruption to existing use and application of various managements tools and adaptation of technologies for climate-resilience (e.g. climate-smart push-pull technology), techniques and strategies to ensure effectiveness of biological control against effects such as, decoupling of pest-natural interactions (e.g. AFERIA and SCLAMP project). The Centre is also using big data, GIS and AI to model and project potential impact including adaption and applicability of various technologies to ameliorate future effect of climate change. These expertise and experience need to be harnessed further through system thinking within the context of One Health for *icipe*'s global impact.

As suggested in the SWOT Analysis, using Climate Change as a One Health concept, *icipe*, through its insect science research, is uniquely positioned to lead regional and global Climate Change research.

We **recommend** that *icipe*, using Climate Change as an overarching factor in the One Health paradigm, continue to strengthen its research on the effect of Climate Change on insects, and how this holistically impacts Plant, Human, Animal and Environmental Health.

10.6 Improving the Utilisation of iTOC at Mbita

The iTOC at Mbita is an ideal and unique location by Lake Victoria, an area where the majority of the residents are smallholder farmers, important stakeholders for *icipe*. It also carries history, being the place where work on PPT started. It is located in Homa Bay County, an area where tsetse flies, malaria-transmitting mosquitoes and Striga weed are highly prevalent.

But it is operating at under-capacity, and activities appear to have significantly reduced. A major factor that deters staff from staying at iTOC is the lack of good medical facilities since the closure of St Jude's clinic. There is no quality and punctual medical service available in Homa Bay. Some *icipe* scientists with family prefer to reside full-time in Nairobi and travel to Mbita for short stays. Other staff residing at iTOC prefer having their family living in Kisumu, 180 km from Mbita, where they go to spend their weekends.

Yet, iTOC still has great potential for future *icipe* projects. It is a natural laboratory for *icipe*'s project on malaria. It provides immense opportunities for further development of the PPT and for more research on the tsetse fly. It has excellent facilities and significant investments have been made for its upkeep. It is important to revitalise the campus.

We understand that the funding model of the Centre, which is donor dependent, does not favour the presence of fixed non-variable costs, as in the case of a clinic. It appears that donors have progressively moved away from core funding which allows for such infrastructure. But donors should be made to appreciate the unique and rural location of iTOC. Due to the potential for One Health related activities in plant, human, animal and environmental health at this site, we believe *icipe* should try to find ways of increasing the utilisation of the campus by ensuring that more research activities take place at iTOC and more scientists live and work there.

Our **recommendations** to *icipe* are as follows:

- a) Develop a strategy to enable the available facilities at iTOC to be more accessible to NGOs and other institutions operating in the region. This will encourage more conferences and meetings to be held there and attract more visitors.
- b) Identify and support more research projects that can be implemented from iTOC.
- c) Improve the provision of health care facilities on the campus to encourage scientists to live and work there. This could be done by creating partnership with the County government for the provision of health care workers, either on a full-time or part-time basis.
- d) Give greater publicity to iTOC in *icipe*'s publications.

10.7 Mainstreaming Youth Employment

Africa is the continent with the fastest-growing youth population in the world. By 2030, there will be 375 million young people in the job market in Africa. In 2010, Africa had 17% of the world's youth; in 2050 that figure will nearly double to 33%⁴. Youth employment is a key measure of socio-economic progress and it helps millions of people to find a pathway out of poverty. Currently, *icipe*'s Vision and Strategy 2021-2025 does not specifically identify youth employment as a strategic focus.

⁴ <https://mastercardfdn.org/our-strategy/young-africa-works/>

We **recommend** that *icipe* mainstreams youth employment in all its 4-Health Theme projects – several of them are already doing that. Eventually, *icipe* could consider creating a separate Youth Employment Unit in its organogram that would service the 4-Health Themes.

10.8 Extension of MOYESH to Other African Countries

The implementation of MOYESH in Ethiopia has had resounding success because of the collaborative approach used, involving all stakeholders, including Government, and the target being women and youth. The Mastercard Foundation has developed a specific strategy (Young Africa Works) to promote and expand employment opportunities for young people in Africa. This explains the Foundation's strong support for MOYESH, as it perfectly aligns with the Young Africa Works strategy as well as the Ethiopian Government's objective of reducing unemployment. The ambitious goal of the Young Africa Works strategy is to enable 30 million young people in Africa, especially women, to secure employment. The Young Africa Works strategy will be implemented using a country-led approach, empowering women, modernising the agriculture sector and working horizontally with African governments, the private sector, NGO's, etc. The focus countries in Africa identified for implementing the strategy are Ethiopia, Ghana, Kenya, Nigeria, Rwanda, Senegal and Uganda.

We **recommend** that *icipe* extends its MOYESH-type project to other African countries. Mastercard Foundation, which has supported MOYESH in Ethiopia, has already expressed interest in supporting *icipe* in such extension. Its Young Africa Works strategy has identified 7 countries, including Nigeria and Senegal, which opens up possibilities for *icipe* to extend its activities to West Africa.

10.9 Traditional African Crops

Traditional African crops, also termed forgotten foods, are gaining traction in the world. The Food and Agriculture Organisation (FAO), the Global Forum on Agricultural Research and Innovation (GFAR), the Forum for Agricultural Research in Africa (FARA) and their partners have highlighted the importance of these crops with a clarion call to increase efforts at integrating them into the African food systems.

At the 8th Africa Agribusiness and Science Week in Durban, South Africa in June 2023, it was stated that mainstreaming forgotten foods is important to address hidden hunger and malnutrition. These crops are good sources of macro- and micro-nutrients for human consumption and have the potential to supply the required energy, vitamins and nutrients in diets, thus reducing the over-dependence on energy-rich foods from animal and other plant-based sources. In addition, women are often the custodians of traditional African crops, growing them for nutrition and income generation.

Traditional African crops fall into five major food classes, namely cereals (e.g. finger millets, pearl millets, teff), legumes (e.g. lablab beans, yam beans, cowpeas, dry beans, soybeans), roots and tubers (sweet potato, coco yams, cassava), and vegetables (e.g. amaranth, black nightshade, black jack, spider flower). They are resilient to climate change, promote biodiversity and are well-adapted to the needs of farmers in marginal agricultural environments. They therefore have the potential to reduce food and nutrition insecurity, particularly for resource-poor households in Africa. These crops, which are often overlooked by policymakers, researchers and extension agents, are increasingly affected by pests as interest in their cultivation grows. *icipe* has characterized the main pests of traditional African vegetables, which include leafwebbers, leafworms, amaranth stem weevils, aphids, leaf beetles, red spidermites, and root knot (RKN) and potato cyst (PCN) nematodes. Eco-friendly and sustainable IPM technologies against these major pests have been identified, but need to be disseminated, while pest complexes of other traditional African crops need to be mapped and combatted with appropriate IPM packages.

We therefore **recommend** that *icipe* emphasises studying and addressing the crop health challenges of a selection of traditional African crops that are affected by pests under its Plant Health Theme, using its comparative advantage of insect research.

10.10 Business Development at *icipe*

Consistent with the strategy of aligning the transfer of technology to global, national and regional agendas, *icipe* has made significant efforts to accelerate uptake of a broader community of end users. This started with their work on Push-Pull and expanded on to various other products that may have consumer appeal, for example honey and honey-bee associated products such as waxes, and other insect-sourced cosmetics for various applications and promotion of sericulture. *icipe* conducted a workshop on Technology Transfer process with external experts and developed a very well-structured Strategy on the Transfer of *icipe*-borne Technologies. On the other hand, the BioInnovate Africa

programme is helping promote the entrepreneurial spirit of the African youth and further supports the employment of women, thus achieving some of the key objectives of the organisation in terms of sustainable poverty reduction.

Although *icipe* has been relatively successful in terms of reaching the community at large, these technologies/innovations emanating from all of *icipe*'s 4-Health Themes may have greater commercial potential and possibly could provide additional opportunities globally, if correctly positioned with the right global markets. For example, the Push-Pull Technology has achieved only limited adoption nationally, though it seems to have all the fundamental elements of 'Regenerative Agriculture' resonating all over the agricultural world. Microbial pesticides have been attracting much attention from investors and private sectors, ever more than before. Other products that may have similar potential are:

- a) Commercial use of microbial strains and metabolites from *icipe*'s own unique collections for biopesticidal activities.
- b) Innovations in insect control such as pheromones, parasitoids, traps for global applications.
- c) Multiple products from the novel and highly innovative INSEFF programme.
- d) Diagnostic tools in the animal and human health industry.

The commercial potential of the innovations at *icipe* (e.g. microbial strain) could likely be enhanced through linkages and possibly out-licensing with select commercial entities. *icipe* must leverage its unique competencies, resources, and capabilities to incubate and commercialize technologies from all its 4-Health Themes for potential use worldwide.

Building on our learnings from the current initiatives and recognising the potential commercial opportunities in this venture, we **recommend** that *icipe* develop a dedicated "Business Development" team with the mission to help evaluate the commercialisation of its technologies. The output should be a 'White paper' on opportunities and approaches to scaling commercial enterprises using *icipe* technologies.

10.11 RSIF: Potential and Limitations

icipe was competitively selected in 2018 for hosting RSIF, a flagship project of PASET for providing PhD scholarships to African students and providing funds for research and innovation. In a relatively short period, RSIF has achieved remarkable success. *icipe* has benefitted from such hosting as it has brought in significant funds to the organisation. It has also enabled *icipe* to partner with a wide range of universities in Africa (the AHUs) and outside Africa (the IPIs). The fact that RSIF is funded mainly by African governments has also been positive for *icipe*.

However, although RSIF is very much aligned with *icipe*'s objective of capacity building, its doctoral programmes are not in areas related to insect science, and therefore relevant to *icipe*. So, unlike *icipe*'s CBID programme, RSIF's research output does not directly benefit *icipe*'s research projects in its 4-Health Themes. In recent years, funding for CBID has been minimal. This means that *icipe*'s capacity building, especially in doctoral education, is increasingly dominated by RSIF. This may have a negative impact in future on *icipe*'s research activities.

There is also some uncertainty about the future of RSIF at *icipe*. Following the end of World Bank's support, PASET is currently undergoing a review on how it is to be operationalised, which would include RSIF. *icipe* has no say in PASET's decision-making. However, it is assured of hosting RSIF up to December 2025. And there is every likelihood that *icipe* will continue hosting RSIF for at least a few more years after 2025.

There has been expectation that RSIF would provide an opportunity to *icipe* for expanding its activities to other African regions. This has not yet happened in view of the way RSIF operates, and future opportunities may be limited.

One issue that applies to both RSIF and CBID PhD graduates concerns the latter's employment. In view of the excellent quality of the graduates, many of them are being attracted by universities and research organisations outside Africa. This brain drain from Africa is detrimental to the continent's development, especially considering that the RSIF graduates are funded by African governments.

The Manager of RSIF resigned a few months ago and he has not been replaced, the Manager of BioInnovate having been entrusted with the additional responsibility of managing RSIF. Both are complex programmes to run and this arrangement may affect the efficiency of both of them.

- We **suggest**:
- a) Both the RSIF and CBID programmes take appropriate steps to minimise brain drain of their graduates.
 - b) Should *icipe* continue to host the RSIF programme beyond 2025, it should appoint a new Manager for RSIF.

10.12 Extension Beyond East Africa

There have been several recommendations in the past on the desirability of *icipe* to extend its activities to African regions other than East Africa, especially to West and Southern Africa, preferably through an established country office. While no doubt the will is there, this has proved to be difficult, mainly because of lack of core funding. The only way *icipe* can open an office in another country is through a funded project, as it has done in the case of Ethiopia and Uganda. There is also an office in Benin in West Africa but it runs a project that is not directly linked to *icipe*'s core R&D activities in insect science.

icipe's strategy for extending beyond East Africa should be, therefore, to look out for projects that target West and Southern Africa. The possibility of extending MOYESH-type activities beyond Ethiopia, as Mastercard Foundation plans to do, offers such an opportunity which needs to be seized by *icipe*. As mentioned earlier, among the countries identified by the Mastercard Foundation are Ghana and Senegal.

But once a project office has been set up, the next challenge would be to ensure its sustainability beyond the project phase to enable its transition to a country office. In Somalia, for example, *icipe* closed its office once the project had ended. There was also perhaps a security issue in Somalia, a matter that *icipe* needs to seriously take into account. To ensure the sustainability of a country office, it needs to be granted a certain degree of autonomy to handle, for example, its finance and human resources. It therefore needs to build management capacity, and also be in a position to search for additional projects in the country.

We **suggest** that, once a country office has been set up, it should be assisted to eventually operate semi-autonomously.

10.13 INSEFF-INSEFOODS Collaboration

As mentioned earlier, *icipe*'s flagship programme on Insects for Food, Feed and Other Uses (INSEFF) has made remarkable progress during the review period.

There is, at the Jaramogi Oginga Odinga University of Science & Technology (JOOUST), a public university in Bondo, western Kenya, an African Centre of Excellence (ACE) on Sustainable Use of Insects as Food and Feeds (INSEFOODS), which was set up in 2016 with funding to the tune of US\$6 million from the World Bank. It is supported by the Government of Kenya. INSEFOODS was established with the purpose of addressing the challenges of sustainable food security using insects as human food and animal feed – almost exactly the same objective as INSEFF. INSEFOODS Centre has also made significant progress and is located not far from Kisumu and also ITOC.

In view of the fact that INSEFF and INSEFOODS work in the same area and are located in the same country, we **suggest** that *icipe* considers promoting a synergistic association leading to a collaboration between the two programmes for the mutual benefit of both organisations.

10.14 Recruitment of Senior Scientists

All research organisations in Africa experience difficulties in recruiting well-qualified, experienced scientists. *icipe* is no exception. A few years back it had considerable difficulty in recruiting the Heads of several of its 4-Health Themes when those retired. A couple of senior scientists, having served *icipe* for several decades and are renowned for their research work, are about to retire this year, and *icipe* will probably face the same challenge.

There is no easy solution to the problem. In 2021, *icipe* increased the retirement age of its scientists from 65 to 68 to continue benefitting from their experience for a few more years. *icipe* also identifies its best PhD or postdoctoral students and recruits them for its research, with the intention of retaining them in the long run. This appears to have worked. Another possibility would be for *icipe* to identify a scientist and have him/her mentored by a senior scientist who would be retiring in a couple of years, basically implementing succession planning. But this is not easy in an organisation which depends solely on research contracts and where all the staff are employed on relatively short (2-3 years) contracts. Ultimately, scientists would be attracted to an organisation which does high quality research, offers a good salary package and has a good working environment. *icipe* qualifies on all these counts.

10.15 Symbiont-based Control of Malaria

The discovery at *icipe* of *Microsporidia MB* which can block the transmission of malaria has the ability to spread through mosquito populations is an example of the importance of conducting basic and applied science in Africa. In the last three years, malaria cases and deaths in Africa have been steadily increasing, which indicates that current control measures and their deployment levels are insufficient. Unfortunately, the situation is expected to get even worse due largely to rising levels of insecticide resistance and the spread across Africa of the invasive malaria vectors. The control and elimination of malaria will only be possible if existing control measures are deployed at higher levels and in conjunction with novel control measures. In this context, the discovery of *Microsporidia MB* has enormous potential for Africa and the world, especially with the spread of malaria to countries where it was never present, because of climate change. The study of transmission blocking symbionts, including *Microsporidia MB*, needs to continue and expand to

meet the urgent need for novel malaria control tools. Symbiont-based strategies should be complementary and integrated with existing control measures for maximum impact.

We **recommend** that the research on *Microsporidia MB* and malaria, although still at trial stage, be pursued aggressively, with the bulk of the work being done at ITOC, Mbita, supported by advanced testing at the Duduville Campus. Support from international organisations such as WHO should be sought as these technologies enter the field trial stages.

10.16 Enhancing Public Awareness through a Permanent Educational Exhibit

While *icipe* has significantly enhanced its technologies, we believe it should also continue to actively promote the organization itself through enhancing public awareness of its activities and the importance of insects to the world, and their role in biodiversity, nutrition and food security. One way of doing this is by creating a permanent educational exhibit emphasizing the unique diversity of insects, their value to the world, and the main accomplishments of this 50-year-old institution. The objective here is to develop an educational centre for children, youth and the community to promote awareness of insects and their value to mankind globally. As the only centre in the world committed to insect sciences, especially in SSA, this could be a lasting legacy for this organisation.

We **suggest** that *icipe* considers, as part of its public service mission, creating a permanent educational exhibit of insects (for example an “Insect Museum”) at its Duduville Campus.

11. CONCLUSIONS

As we complete our review of the only institution in the world dedicated to studying insects, it behoves us to conclude by reflecting on the importance of insects to humanity and thus the service of *icipe* to the world.

Why insects? What would the world be without insects? Insects are the foundation of life; a business analysis conducted by the University of Florida estimated the economic value of insects to the United States economy alone as approximately \$70 billion per year.⁵ Insects have a critical role in pollination; it is important to note that without pollination many of the produce that we take for granted such as apples, cherries, almonds, and several other life-sustaining crops would not exist. Although over 3000 species of mosquitoes remain a nuisance and are carriers of major diseases such as malaria and filaria, several of these nuisance pests are the primary food of many animals such as bats and lizards which are integral parts of the food chain of many other animals. Insects also provide essential food for many humans in several parts of the world and are an excellent source of proteins. Insects are the primary decomposers of many of the organic and inorganic wastes, including plastics, which facilitate their recycling.

Our learnings at *icipe* have convinced us of the role of insects and hence *icipe* in this world. To save ourselves, we need to save insects. As part of the global efforts to bring about systemic change to fix agriculture, the world has started looking at options of going back to nature, and *icipe*'s approach at targeting smallholder farming at the ground level is an effort at reviving the regenerative agricultural practices using the best that science has to offer. This is the purpose of this organisation.

Over the past fifty years of its existence, *icipe* has grown into a world-class research-for-development (R4D) organisation with insects at its heart. Connecting the science of insects to the four pillars of Plant, Human, Animal, and Environmental Health, as *icipe* has done, and attempting to interlink them through One Health, is the best approach to address the challenges of smallholder farmers in SSA and the world. The outputs are correlated to the societal and social impacts in terms of poverty reduction, dietary/nutritional improvements and overall well-being of the communities served, providing the ultimate metric that helps deliver on the One Health concept.

The Centre has been recognised globally by international organisations such as the FAO, WHO, and the World Bank, in addition to various for-profit and non-profit organisations. The numerous awards and recognitions received during this period of review as well as the significant increase in the number of donors over the past five years are further evidence of global recognition. The Centre is well-endowed with a remarkable infrastructure of world-class laboratories as well as equipment matching any other high-end research institution. The quality of research work is also of the highest level and demands special mention. In the past five years, we witnessed a noticeable upward shift in the quantity and quality of publications in some 1,000 scientific papers published in peer-reviewed journals and a high percentage of publications in journals with Impact Factor of 2 and above. The total citations of *icipe* papers have also increased consistently over this period. These are very important merit-worthy metrics for a scientific organisation. The vision of the founding Director of *icipe*, Prof. Thomas Odhiambo, of establishing an African research powerhouse that can provide solutions to Africa's unique challenges through insect science continues to be realised and expanded with the help of advanced technologies and significantly more resources.

Much of the credit goes to an experienced and talented management team, many of whom have been at post for several years and are clearly aware of the mission and vision of the organisation and are aligned with its values. The scientists are of the highest calibre, with advanced degrees from reputed academic institutions from around the world. They are supported by highly efficient and trained, technical, business, and administrative staff who also have been at the Centre for quite some time. Over our review period, the team has been led by a Director General who is an accomplished scientist and globally respected for her scientific leadership. The outstanding leadership has been closely supported by an excellent talented management team, and key scientists who lead the programmes in the plant/animal/environmental/human and social sciences sector. *icipe*'s scientists are also highly recognised in their fields and their publications are often cited and have earned a reputation as the top 2% of scientists in the world. Several of them in fact started their research career at *icipe*, including two of the most senior and renowned scientists who are about to retire.

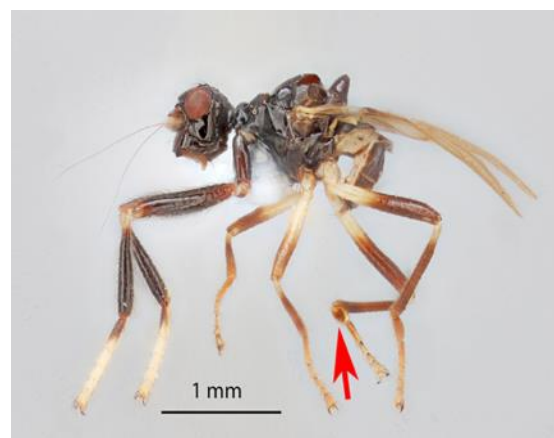
The work at *icipe* has also gained increased media attention over the past few years. Its motto "Insects for Life" launched at *icipe*'s Golden Jubilee celebrations in 2020 was globally communicated through various media channels. Of more recent academic interest is the "Insect of the Week" digital communication from *icipe* that draws attention to the notable capabilities of the Biosystematics Unit at the Centre, which has procured advanced digital tools capable of documenting the unique features of the insect world through simple but very clear photographs, detailing the morphological features

⁵[The Insect Effect: Insect Decline and the Future of Our Planet – Thompson Earth Systems Institute \(ufl.edu\)](https://www.thompsonearth.com/news/the-insect-effect-insect-decline-and-the-future-of-our-planet/)

complemented with an accurate scientific description. This Unit at *icipe* has likely the most advanced insect identification systems and has been providing its service to many partner organisations.

“If Fred Astaire was an insect, he might have been an *Afromiya*” states a recent “Insect of the Week” communication from the Biosystematics Unit, referring to the following educational photograph and description taken using its newly-acquired camera, lens attachments and digital tools, a generous contribution from Sida. The insect identified here is *Afromyia wittei*, an adult fly of the family *Sphaeroceridae*, in the subfamily *Sphaerocerinae*. The genus *Afromyia* is an African endemic and has an important role in recycling wastes.

But like any organisation, especially one that is almost entirely dependent on donor funding, *icipe* has faced challenges and will invariably do so in the decade ahead. We acknowledge that many of these challenges are external, over which *icipe* has no control, such as global events or shifting donor priorities. But others can be addressed by *icipe* as we have outlined in our recommendations and suggestions.



We are conscious of the fact that an entirely new senior management team will soon take over the leadership of the Centre – that in itself will pose a challenge. But we are confident that the foundation of the organisation is solid; what is required is a new team that is dedicated to high quality science, respectful of *icipe*'s values, mission and vision, devoted to Africa's development, steadfast on transparency and accountability, and committed to maintaining the trust of donors so that, under the wise guidance of the Governing Council, it can steer the organisation to even greater heights. It is from that perspective that our recommendations and suggestions must be considered.

Acknowledgements

It has been such a privilege to undertake a review of this prestigious organisation, and we are grateful to *icipe*'s Governing Council and senior management for giving us such an opportunity. We wish to express our thanks to *icipe*'s senior management and heads of the Themes and Units for compiling the comprehensive document “Overview of *icipe*'s Achievements 2018-2022”, and for the presentations and discussions during our visit to the Centre, which helped us enormously in our assignment. Our conversations with other researchers, students and technical staff at Duduville, the country office in Ethiopia, the iTOC in Mbita and the Muhaka field station also proved very useful, and we are grateful to them for sparing their time. We equally thank the staff at the Guest Houses in Duduville and Mbita for making our stay so comfortable and enjoyable, and to the chauffeurs who took us around for our visits at odd hours. Above all, we express our appreciation to Annah Njui and her team for dealing with our complicated travel schedules and for making all the arrangements for our visits and meetings.

We wish continued success to *icipe*.

Goolam Mohamedbhai (Chair)

Felister Makini

Prem Warrior

ANNEX 1

icipe Management Response to the icipe Periodic External Review (IPER) 2018–2022 Recommendations

The *icipe* Governing Council (GC) and Management thank the IPER Panel for their review of the Centre's research and development (R&D) activities, as well as its administration and management. In the following section, we provide specific responses to each of the IPER recommendations.

10. CHALLENGES AND OPPORTUNITIES: COMMENTS, SUGGESTIONS AND RECOMMENDATIONS

In this section, we summarise our learnings based on our extensive readings and visits, as well as our meetings and conversations with a wide range of *icipe*'s staff, beneficiaries, donors and other stakeholders. We identify some challenges, not only those already encountered but also those that could arise in the future. Many of *icipe*'s challenges arise from the fact that it is an institution which is almost entirely dependent on donor grants. We also point out opportunities, provide our comments and, where relevant and appropriate, offer suggestions and propose recommendations.

10.1 SWOT Analysis of *icipe*

In 2020, in preparation of its V&S 2021-2025, a SWOT Analysis of *icipe* was carried out with the collaboration of *icipe*'s senior management and scientists. We found the Analysis very pertinent as it corroborates several of our findings. This SWOT Analysis would be extremely useful to the new leadership team of *icipe*. (Many of *icipe*'s challenges arise from the fact that it is an institution which is almost entirely dependent on donor grants.)

icipe Management response:

The SWOT analysis remains current and clearly demonstrates the framework that has been available to Management for the continuous evaluation of the Centre's competitive position and for the implementation of the V&S 2021-2025. We note the review team found the tool useful and complete and that it would be of continuing value to the new Centre leadership.

The SWOT analysis does identify several organisational challenges but *icipe* has management practices to address them including those relating to donor funding. *icipe* is not unique in being dependent on funders. ALL of the CGIAR Centers and a number of other non-CGIAR R&D centers are dependent on external donor funding. *icipe*, because of its uniqueness, the relevance of its science and the impact it is making has been very successful in resource mobilization, building partnerships, and impact. We do not see resource mobilization as a challenge as long as *icipe*'s science continues to be relevant and the translation of its science to impact continues to make a difference in people's lives and the environment.

10.2 Change in Senior Leadership Team

The decision of whether or not to recruit a DRP has been left to the new incoming senior management team. If the new team decides to maintain the same governance structure as before, we would **suggest** that a new DRP be recruited. Another possibility, one evoked in the SWOT Analysis and our preferred option, is that a more devolved governance system be adopted, with leadership shared with the Heads of the Four Health Themes.

icipe Management response:

In the previous years before this administration, *icipe* did not have a Director of Research and Partnership position. The DG, as the Chief Scientific Officer of the Centre, would discharge the responsibilities of that position. With the growth of the Centre, the current leadership created the position and there have been two DRPs in the past eight years. Following a request by the most-recent incumbent to move back to research and capacity building, the position was left vacant with the DG again discharging its responsibilities. While preparation for the recruitment has been completed and an initial search undertaken, as the change in current leadership came closer it was agreed that it would be in the best interest of the Centre if the option to fill the position was left to the incoming leadership. The expected limited period of vacancy does not pose a significant risk since the Theme Leaders are members of the Senior Management Committee and are fully engaged in the running of most of the R4D activities.

10.3 Future Funding Challenge and Resource Mobilisation

While applauding the excellent efforts in resource mobilization made by *icipe* over the review period, we **recommend** as follows:

- a) To continue the expansion of the donor base to also include donors and funding agencies from Africa.
- b) To reactivate the Sponsoring Group of *icipe* (SGI) which operates under the GC. The group should perhaps be enlarged to include other *icipe* donors as well. The issue of core funding for *icipe* should be high on the SGI's agenda.
- c) To provide more resources to the Resource Mobilisation Unit to enable it to access additional digital tools for searching availability of research grants internationally.

icipe Management response:

- a) *icipe* has been highly successful in its resource mobilization drive, bringing in 66 new funders to its funding portfolio including 15 Foundations and 10 African governments. This has been an extraordinary result in *icipe*'s history. *icipe* has even received first-time funding as a beneficiary of the estate of a late Dutch publisher.
- b) Between 2016 to 2019, under the leadership of Biovision Foundation, there was concerted effort to revive the SGI, and its terms of reference were revamped and various donors approached to join the grouping. There has been momentum with members of the group consulting on various matters and reaching out to other donors. The Chair of the SGI moved to SDC from 6 November 2020. The SGI is currently active, and the group may, as need and opportunities arise, expand its membership.
- c) *icipe* resource mobilization is a team effort in which all, including Management, scientists, and finance staff, are fully engaged. The Unit works closely with these teams to identify target funders and the necessary resources and tools for reaching and turning them into funders. It is this team effort that has generated the past resource mobilization successes.

10.4 Adoption of *icipe* Technologies in Rural Areas in Kenya

Our **recommendations** to *icipe* are as follows:

- f) Undertake a study, through the SSIA and the TT Units, to establish the causes hindering adoption of *icipe* technologies in Kenya e.g., the persistence of Striga weed in the case of PPT or the use of repellents for the tsetse flies.
- g) Make more concerted efforts to engage County governments in Kenya, through the Council of Governors, in implementing projects in rural areas.
- h) Provide opportunities to relevant authorities in Kenya to visit the technology sites to enable them to understand these technologies and appreciate their impact.
- i) Strengthen linkages with multiplier organisations such as NGOs, media and the National Plant Protection Organisation of Kenya for direct transmission of technologies at local level.
- j) In order to stimulate demand for improved technologies, develop a web-mobile application for information on *icipe*'s innovations and technologies to create a direct interaction between research users and promoters involved in technology generation or transfer.

icipe Management response:

- a) The Social Sciences and Impact Assessment Unit of *icipe* has conducted and published several studies including research that explicitly investigates the factors influencing adoption decisions, and other studies assessing adoption as a component of impact analyses. This is not new to *icipe*. It is part of the main tasks of the Social Sciences and Impact Assessment Unit. Below is a list of some selected papers.

Push-Pull Technology Adoption Studies:

1. Balew, S., Bulte, E., Abro, Z., & Kassie, M. (2023), Incentivizing and nudging farmers to spread information: Experimental evidence from Ethiopia. *American Journal of Agricultural Economics*, 105(3), 994-1010. <https://doi.org/10.1111/ajae.12346>
2. Murage AW, Pittchar JO, Midega CAO, Onyango CO, Pickett JA & Khan ZR (2019), Gender appropriateness of field days in knowledge generation and adoption of push-pull technology in eastern Africa, *East African Agricultural and Forestry Journal*, 83:4, 289-306, DOI: [10.1080/00128325.2019.1644145](https://doi.org/10.1080/00128325.2019.1644145)
3. Muriithi, B.W., Menale, K., Diiro, G. *et al.* (2018), Does gender matter in the adoption of push-pull pest management and other sustainable agricultural practices? Evidence from Western Kenya. *Food Security* 10, 253–272. <https://doi.org/10.1007/s12571-018-0783-6>

4. Kassie, M., Stage, J., Diro, G., Muriithi, B., Muricho, G., Ledermann, S. T., Pittchar, J., Midega, C., & Khan, Z. (2018), Push–pull farming system in Kenya: Implications for economic and social welfare. *Land Use Policy*, 77, 186–198. <https://doi.org/10.1016/j.landusepol.2018.05.041>
5. Murage, A.W., Midega, C.A.O., Pittchar, J.O. *et al.* (2015), Determinants of adoption of climate-smart push-pull technology for enhanced food security through integrated pest management in eastern Africa. *Food Security*, 7, 709–724. <https://doi.org/10.1007/s12571-015-0454-9>
6. Chepchirchir, R. T., Macharia, I., Murage, A. W., Midega, C. A. O., & Khan, Z. R. (2017). Impact assessment of push-pull pest management on incomes, productivity and poverty among smallholder households in Eastern Uganda. *Food Security*, 9(6), 1359–1372. doi:10.1007/s12571-017-0730-y

Integrated Pest Management (IPM) for Fruit Flies Adoption Studies

1. Niassy, S., Muriithi, B., Omuse, E. R., Kimathi, E., Tonnang, H., Ndlela, S., Mohamed, S., & Ekesi, S. (2021). Insight on Fruit Fly IPM Technology Uptake and Barriers to Scaling in Africa. *Sustainability*, 14(5), 2954. <https://doi.org/10.3390/su14052954>
2. Midingoyi, G., Kassie, M., Muriithi, B., Diro, G., & Ekesi, S. (2019). Do Farmers and the Environment Benefit from Adopting Integrated Pest Management Practices? Evidence from Kenya. *Journal of Agricultural Economics*, 70(2), 452–470. <https://doi.org/10.1111/1477-9552.12306>
3. Wangithi, C. M., Muriithi, B. W., & Belmin, R. (2021). Adoption and dis-adoption of sustainable agriculture: a case of farmers' innovations and integrated fruit fly management in Kenya. *Agriculture*, 11(4), 338. <https://doi.org/10.3390/agriculture11040338>
4. Mulungu, K. Abro, Z., Muriithi, B., Kassie, M., Kidoido, M., Sevgan, S., Mohamed, S., Tanga, C., and Khamis, F. (2023). One size does not fit all: Heterogeneous economic impact of integrated pest management practices for mango fruit flies in Kenya—a machine learning approach. *Journal of Agricultural Economics*, <https://doi.org/10.1111/1477-9552.12550>.
5. Otieno, S. J., Ritho, C. N., Nzuma, J. M., & Muriithi, B. W. (2023). Otieno, S.J.; Ritho, C.N.; Nzuma, J.M.; Muriithi, B.W. (2023). Determinants of Adoption and Dis-Adoption of Integrated Pest Management Practices in the Suppression of Mango Fruit Fly Infestation: Evidence from Embu County, Kenya. *Sustainability*, 15, 1891. <https://doi.org/10.3390/su15031891>

Tsetse Repellent Collar Technology adoption study:

1. Muriithi, B.W., Menale, K., Diro, G.M. *et al.* (2023). Effect of use of tsetse repellent collar technology on the farm performance and household welfare of small-scale livestock farmers in Kenya. *Food Security* 15, 751–770. <https://doi.org/10.1007/s12571-022-01342-4>

b) Technology adoption work is largely the function of government agencies and National Agricultural Research Systems (NARS) and *icipe* cannot go from county to county in each of the 42 African countries in which it operates. Nonetheless, *icipe* uses multiple pathways to adoption and impact (see details in section c & d below). For example, once we introduced the push-pull technology and demonstrated its effectiveness in Rwanda, the Government of Rwanda moved it to a large scale, as is seen in these articles with the full acknowledgement of and collaboration with *icipe* [Rwanda: Govt Launches Campaign Against Fall Armyworms - allAfrica.com](#); [Govt launches campaign against fall armyworms \(newsexplorer.net\)](#). The Government of Ethiopia had done the same by engaging its Ministry of Agriculture and extension agencies.

c & d) The Push-pull dissemination strategy involved communication of the technology information through multiple pathways and partners for its widescale uptake by farmers in Africa, while ensuring adequate policy acceptance and sustainable adoption. The strategy involved designing and implementing technology promotion events and working with partners in focal regions of each country as nodes to expand to new potential areas. The strategy for implementation of promotion events was constantly reviewed and adjusted, informed by results being generated from each country. Key stakeholders were identified, and their roles defined to work through multi-actor communities of practice (MACs) with country-based partners in planning delivery of, and communicating, technology information through previously tested cost-effective dissemination pathways. The country teams defined the right strategies for disseminating technology information within their local contexts to targeted farmer groups, and implemented the most appropriate and effective training modules, schedules and processes, and linkages through their MACs.

The partners adopted targeted farmer-to-farmer information transfer methods that enhanced gender-equity. The partners established strategic technology learning sites to visually demonstrate the technology in each target area, and in new sites identified for technology expansion. The partners organized farmer field days in the target areas each cropping season and conducted “training of trainers” workshops. They identified, trained, and worked with government and private local agricultural advisers to effectively promote the benefits of the technology and facilitate its wider uptake. Training events were organized through natural formations of farmer groups linked to available government resource centres and input suppliers.

In the past 5 years Push-pull was disseminated to **18 countries in Sub-Saharan Africa** through *icipe*'s Technology Transfer Unit, working through more than thirty-three (33) partners. Existing partnerships were maintained, and new partnerships established for adaptation, validation and scaling up of the technology. These include the Institute for Sustainable Development, Agricultural Transformation Agency and Ethiopia Institute of Agricultural Research (EIAR) in Ethiopia; Tanzania Agricultural Research Institute in Tanzania; Send a cow (now Ripple Effect), East African Farmers' Federation (EAF), Maseno University, Jomo Kenyatta University of Agriculture and Technology (JKUAT), and Kenya Agriculture and Livestock Research Organization (KALRO) in Kenya; National Agricultural Research Organisation (NARO) and Poverty Alleviation Department in Uganda; Rwanda Agriculture Board, Ripple Effect and Food for the Hungry (FH) in Rwanda; Total Land Care, Lilongwe University of Agriculture and Natural Resources (LUANAR), Department of Agriculture Research (DARS) in Malawi; Kasisi Agricultural Training Centre, Conservation Farming Unit, University of Zambia, Zambia Agriculture Research Institute (ZARI) in Zambia; Kushereketa Rural Development Organization (KURDO), SCORE against poverty and Department of Agricultural, Technical and Extension Services (AGRITEX), Mukushi seeds company, Gwebi Agriculture college in Zimbabwe; Institut des Sciences Agronomiques de Burundi (ISABU) and Food for the Hungry (FH), in Burundi; University of Dakar and SECAAR in Senegal and Togo; Institut de l'Environnement et de Recherches Agricoles (INERA) and Ministry of Agriculture in Burkina Faso; Crop Research Institute, Bamboo Research Institute in Ghana; Institut National pour l'Etude et la Recherche Agronomique, (INERA, Congo); and GRAPHE in Togo.

Both *icipe* and partners used mass media broadcasts to create primary awareness of Push-pull technology. Over 21.6 million people were reached through mass media broadcasts. Several training and dissemination videos were developed and promoted through partner networks and social media (for young farmers). Further mass reach was achieved through partner websites and social media. The push-pull website, www.push-pull.net, receives more than 80,000 hits monthly. An example of an online knowledge exchange hub with a wider reach, <https://upscale-hub.eu/>, is implemented by *icipe* and UPSCALE project partners.

A sample of the videos developed and distributed by *icipe* and partners is presented hereunder:

- <https://youtu.be/WxjHHWLDkZI?si=v17PoGJLSsuyIfw4>
- <https://youtu.be/7qQTthKeX5M?si=HVtonNE91IJ14nhJ>
- <https://youtu.be/rI7td5gv10I?si=lzYWRmbyoueomL1S>
- <https://youtu.be/WkRW966qhdo?si=SXRU1FfQ8IAtkQWq>
- <https://youtu.be/rI7td5gv10I?si=lzYWRmbyoueomL1S>
- <https://www.youtube.com/watch?v=O5N-h7eTFR4>
- <https://www.youtube.com/watch?v=ZwChseDEe3E>
- <https://www.youtube.com/watch?v=O5N-h7eTFR4>
- <https://www.youtube.com/watch?v=MLDm74DTWCq>
- https://www.youtube.com/watch?v=XY_m-gemNMw
- <https://www.youtube.com/watch?v=Uoq8KV4L7zI>
- https://www.youtube.com/watch?v=jt3_ThBDTC8
- <https://www.youtube.com/watch?v=NfyHa8e9hDI>
- <https://www.youtube.com/watch?v=qelwgZ9LCts>
- <https://www.youtube.com/watch?v=NHK1TOFS5Gg>

Complementary to all outreach events, simplified printed materials were produced, translated into local languages, and distributed during road shows, field days, farmer training events, and school visits. The printed materials include flyers, brochures, training manuals and farmer field school curricula.

The brochures (<http://www.push-pull.net/dissemination.shtml>) include:

- i) Upscaling the benefits of push pull technology for sustainable agricultural intensification in East Africa (UPSCALE push-pull brochure),
- ii) Push pull controls the fall armyworm menace and
- iii) Use the climate smart push-pull technology.
- iv) Cartoon book for school children

Training manuals included:

- (i) Push pull curriculum for farmer field schools and
- (ii) A step-by-step guide for farmers and extension staff

In summary, farmers were reached through the following pathways during the last 5 years:

Outreach pathway	Number	Reach	Secondary reach
Demonstration sites	128	94,000	
Training of Trainers Workshops	420	10,500	157,500
Farmer group training events	3,841	115,230	345,690
Farmers' field days	665	133,000	

e) We are using Information and Communication Technology (ICT) tools to make the supply chain less cumbersome and accessible at costs farmers can afford. These tools and technologies include:

- The LiMA Application that has been piloted, and is now being further developed for full deployment through the Bioinnovate Bioventure Hub (<https://bioinnovate-africa.org/creating-a-global-hub-for-the-bioeconomy-composing-a-protocol/>).
LiMA is available on Google App
Store: <https://play.google.com/store/apps/details?id=com.mhealth.icipe.mobivet&hl=en&gl=US&pli=1>
- Rwanda Fall Army Worm, Climate stress & Striga Forecasting & Monitoring: <http://wca-rwanda.icipe.org/>
- Vector Atlas project (<https://vectoratlas.icipe.org/>). Near-real time documentation and advisory for malaria mosquitoes. Plans are underway to expand this to other disease vectors. Partners include malaria control programs in endemic countries in Africa.
- Centre-wide Monitoring and Evaluation Data Collection system: <https://odk-server.icipe.org>.
- Web-based knowledge exchange hub within UPSCALE project: <https://upscale-hub.eu/>. This Knowledge Exchange Hub (KEH) is a platform for sharing information on sustainable intensification practices, including push-pull practices in different systems and regions of Eastern Africa.

10.5 Using Climate Change as a One Health Concept

We **recommend** that *icipe*, using Climate Change as an overarching factor in the One Health paradigm, continue to strengthen its research on the effect of Climate Change on insects, and how this holistically impacts Plant, Human, Animal and Environmental Health.

icipe Management response:

The interconnectedness of climate, insects, and overall health is an area that *icipe* is already focused on. At *icipe*, we have been actively engaged in research and initiatives that address the multifaceted challenges posed by Climate Change in the context of our 4-H paradigm. Below are some concrete examples of the work being carried out by the institution.

Identify, map, and characterize hotspot locations prone to pests and diseases with significant implications for One Health under changing climates: Our approach involves a multifaceted strategy to identify, map, and comprehensively characterize hotspot locations that are particularly vulnerable to pests and diseases, thereby presenting significant implications for the One Health paradigm amid a changing climate. We initiate the process by identifying regions and ecosystems that are at heightened risk due to changing climatic conditions. This identification is based on historical data, climate change projections, and the known distribution of disease vectors and pests. Once identified, we proceed to map these hotspot locations. Advanced geospatial techniques and remote sensing technologies are employed to create detailed maps that highlight the geographical extent of these hotspots. These maps provide a visual representation of areas susceptible to health-related challenges, integrating data on vector habitats, host populations, and climate variables. Characterizing hotspots involves a comprehensive analysis of various factors contributing to their susceptibility. We delve into the ecological, epidemiological, and environmental components of these regions. This includes studying factors such as temperature trends, precipitation patterns, host plant distributions, and wildlife populations. We also consider socioeconomic factors, including human population density and access to healthcare. Our characterization considers the One Health paradigm, which emphasizes the interconnection of human, animal, plant, and environmental health. We assess the potential impacts of disease and pest outbreaks on human populations, domestic and wild animals, and the broader ecosystem. This holistic perspective ensures that our analysis considers the multifaceted nature of health challenges. To quantify the risk posed by these hotspots, we conduct rigorous risk assessments. This involves evaluating the likelihood of disease transmission, the vulnerability of populations, and the potential consequences of outbreaks. Risk assessment tools and modelling techniques are used to predict future scenarios under changing climate conditions. With this systematic approach, we provide actionable insights into areas facing heightened risks related to pests and diseases within the context of a changing climate. These insights empower

decision-makers and stakeholders to implement targeted interventions and strategies that uphold the principles of One Health and mitigate the potential health impacts on humans, animals, and the environment.

Optimizing the deployment of climate-smart one-health integrated pest management (CS-OH IPM): This is a comprehensive and strategic endeavour designed to effectively tackle the intricate challenges presented by climate change, pest management, and public health within the overarching framework of the One Health paradigm. This optimization process encompasses several critical components: data collection, involving systematic gathering of climatic variables, pest populations, and disease vector data; continuous monitoring to detect shifts in environmental conditions; advanced analytics employing statistical modelling and artificial intelligence for uncovering hidden patterns; predictive modelling to anticipate pest outbreaks and disease transmission; timely interventions based on data analysis; and comprehensive risk assessments that inform proactive measures. In essence, this approach empowers stakeholders with actionable insights, enabling them to respond effectively to emerging threats, allocate resources efficiently, and proactively address the dynamic challenges posed by climate change, pest management, and public health within the context of One Health. In the study titled "Data-Driven Artificial Intelligence (AI) Algorithms for Modelling Potential Maize Yield under Maize–Legume Farming Systems," advanced AI algorithms were employed to model the potential maize yield within maize-legume farming systems in East Africa. This research leverages AI techniques to harness a wealth of data sources, encompassing climatic factors, soil characteristics, historical crop yields, and agronomic practices. The resulting model holds significant promise in the realm of sustainable agriculture, offering invaluable insights to farmers, researchers, and policymakers. These insights shed light on how various factors, such as climate change, soil quality, and crop rotation choices, impact maize yields. This knowledge empowers stakeholders to make informed decisions aimed at optimizing agricultural practices and mitigating potential risks stemming from climate variability and change.

Climate-resilient crop-pest-parasitoids interactions research: Our climate-resilient crop-pest-parasitoid interactions research represents a continuous and comprehensive exploration of these intricate ecological relationships. We are particularly concerned with the implications of global warming, which is a pressing concern in the context of climate change and interaction between plant, insect pest and their natural enemies. Within this research, we delve into the multifaceted effects of rising temperatures and atmospheric CO₂ on various facets of plant physiology. This includes an in-depth analysis of metabolic processes and the nutritional composition of plants, as these factors play pivotal roles in plant health and resilience. Understanding how these plant characteristics are influenced by climatic shifts is crucial, as they have direct repercussions on the behavior and feeding patterns of insect pests. In addition to the impact on pests, these climate-induced alterations within the plant kingdom can disrupt the delicate balance between insects and their natural adversaries, such as parasitoids and predators in the ecosystem. Changes in plant quality and availability can lead to mismatches in the life cycles and behaviors of these organisms, potentially affecting pest control mechanisms that rely on the natural enemies of pests. Overall, this research aims to provide a nuanced understanding of the complex interplay between climate change, plant-insect interactions, and the broader ecosystem. This knowledge is indispensable for developing climate-resilient agricultural strategies and safeguarding food security in the face of a changing climate.

10.6 Improving the Utilisation of iTOC at Mbita

Our **recommendations** to *icipe* are as follows:

- a) Develop a strategy to enable the available facilities at iTOC to be more accessible to NGOs and other institutions operating in the region. This will encourage more conferences and meetings to be held there and attract more visitors.
- b) Identify and support more research projects that can be implemented from iTOC.
- c) Improve the provision of health care facilities on the campus to encourage scientists to live and work there. This could be done by creating partnership with the County government for the provision of health care workers, either on a full-time or part-time basis.
- d) Give greater publicity to iTOC in *icipe*'s publications.

icipe Management response:

There are limitations placed on *icipe*'s ability to fully pursue an open-door policy due to its headquarter agreement. The latter bestows certain privileges and immunities on *icipe* and recognises the extraterritoriality of its places of operation. This puts limitations on the type of organizations that *icipe* can legitimately allow to operate within its premises and limits activities with third parties. This reality means that only a handful of organizations, indeed only those that enjoy similar conditions, qualify as a target. *icipe* cannot therefore operate the campus in a commercial manner and this has led to excess unused capacity at iTOC. In addition, even internally, the location of the campus, far from the usual facilities and amenities that Scientists are accustomed and expect, limits its use and since alternative locations do exist, there are usually no compelling reasons to place projects at Mbita, especially given the added logistical costs that arise due to the location. Despite this, the campus has operated at similar levels over the past decade and considerable upgrades have taken places in those areas where opportunities existed – completion of construction of an arthropod containment

laboratory for malaria vector research, completion of construction of student apartments, installation of solar photovoltaic systems, and upgrades of the electrical system, the guest house and water systems.

During the period, however, a review indicated that the continued running of a medical clinic was no longer viable because the usage by the staff target group was minimal, there were no sustainable funds to subsidize its deficit of USD 60K p.a., and the supervision of a medical clinic was outside the ambit of *icipe*. Initial search for an industry provider to locate at the clinic proved unsuccessful and with the onset of COVID-19 pandemic, the matter was permanently suspended. However, on closure of the clinic, alternative medical facilities were identified at Homa Bay (half an hour away), and evacuation measures were put in place in the case of emergencies. The latter have been tested on two occasions and found to be sound. The Centre continues to work to bring closer medical services and there has been discussion with its insurer to approve two additional providers based at Mbita.

Over the period, Management was also focused in ensuring resources were deployed where they provided optimisation such as moving away from local concentration towards a more regional and Africa-wide focus. This required difficult decisions of moving away from legacy structures such as *ITOC*.

10.7 Mainstreaming Youth Employment

We **recommend** that *icipe* mainstreams youth employment in all its 4-Health Theme projects – several of them are already doing that. Eventually, *icipe* could consider creating a separate Youth Employment Unit in its organogram that would service the 4-Health Themes.

icipe Management response:

The primary mandate of *icipe* is to conduct research that promotes integrated management of crop and livestock insect pests, other related arthropods, and insect vectors of tropical diseases, harnessing the value of beneficial arthropods, and strengthening scientific and technological capacities of developing countries in insect science and its application through training and partnerships. While youth employment is already of significance within the Centre's R4D, this is driven by the Themes to ensure *icipe* maintains its core mandate focus. The Themes working with the SSIA Unit have led to youth employment as well as gender equality being embedded and integrated in all the research proposals, technologies and products generated. Where needed, financial inclusion and value chain analysis are also fully integrated in some programmes such as YESH and MoYESH. The Centre's activities are directly engaged with creating and delivering products within programmes such as Insects for food, feed, fertilizer, and other uses; MoYESH and YESH; push-pull technology, biopesticide production and processing, and several others that create jobs along the value chains. *icipe* does not see much relevance in establishing a separate unit for youth employment though. Establishing units require major resources and in this case, it may not add significant value.

10.8 Extension of MOYESH to Other African Countries

We **recommend** that *icipe* extends its MOYESH-type project to other African countries. Mastercard Foundation, which has supported MOYESH in Ethiopia, has already expressed interest in supporting *icipe* in such extension. Its Young Africa Works strategy has identified 7 countries, including Nigeria and Senegal, which opens up possibilities for *icipe* to extend its activities to West Africa.

icipe Management response:

During the review period, we had informed the IPER team of our intentions and of the year-long discussion with the MasterCard Foundation to expand the successful R4D on beekeeping and silk in Ethiopia to other parts of Africa. To that effect, *icipe* has been invited to submit idea notes for consideration and these are currently under review by the funder.

10.9 Traditional African Crops

We therefore **recommend** that *icipe* emphasises studying and addressing the crop health challenges of a selection of traditional African crops that are affected by pests under its Plant Health Theme, using its comparative advantage of insect research.

icipe Management response:

icipe and partners have worked/are working on traditional African vegetables (TAVs) through the following large projects:

- 'Enhancing the livelihood opportunities of smallholder African indigenous vegetable (AIV) producers through the development and implementation of IPM measures for arthropod and nematode pests (AIV-IPM)', 2014-2017, funded by BMZ, countries: Kenya and Tanzania.
- 'Diversifying food systems: horticultural innovations and learning for improved nutrition and livelihood in East Africa (GLOBE-HORTINLEA)', 2013-2018. Funded by BMBF, countries: Kenya and Tanzania.
- 'Intensified agroecological-based cropping systems to enhance food security, environmental safety and income of smallholder producers of crucifers and traditional African vegetables in East Africa (Agroveg)', 2022-2024, funded by Biovision Foundation, countries: Kenya and Tanzania.

Achievements so far:

- **We have, for the first time, characterized biotic constraints of key TAVs** (amaranth and African nightshade). The most important pests on amaranth were Lepidopteran defoliators (the leafwebbers *Spoladea recurvalis* and *Udea ferrugalis*; the armyworms *Spodoptera exigua*; *Spodoptera littoralis*), aphids (*Myzus persicae* and *Aphis gossypii*) and beetles (*Hypolixus nubiliosus*, *Hypolixus truncatulus*, *Baris* sp, *Apion* sp, *Epicauta albovita*, *Platynapsis sexguttata* and *Brumoides fulviventris*). On nightshade, the most important groups of pests recorded were spidermites (*Tetranychus evansi* and *Tetranychus urticae*), aphids (*A. gossypii* and *M. persicae*) and flea beetles (*Epitrix silvicola*, *Phyllotreta* sp. and *Luperodes quaternus*). A virus new to science, the nightshade veinal mottle virus (NsVMV), was reported on nightshade and is transmitted by aphids. Rootknot nematodes and potato cyst nematodes were identified as major constraints to TAV production. The quarantine nematode *Meloidogyne enterolobii* was reported for first time in East Africa and was found damaging nightshade.
- **We have developed IPM technologies for key TAVs.** Augmentative biocontrol with parasitoids: *Apanteles hemara* was identified as an excellent indigenous natural enemy of amaranth leafwebbers. *Cotesia icipe* was identified as an efficient parasitoid of amaranth armyworms. *Aphidius colemani* is an efficient parasitoid of aphids on amaranth and nightshade. Resistant germplasm: Five leafwebber-resistant amaranth accessions were identified. In addition, some accessions exhibited high resistance to the complex of defoliators and weevils, making them appropriate to be used as 'dead-end' trap crops in push-pull or mixed cropping systems. Pheromones: Phenylacetaldehyde (PAA), reported to be efficient attractant for *S. recurvalis* in the Americas, was found inefficient against the African population. Biopesticides: *Metarhizium anisopliae* ICIPE 30 was found effective against adult *S. recurvalis*. *M. anisopliae* ICIPE 62 was found effective against *A. craccivora*, especially when combined with intercropping cowpea and maize. *Bacillus subtilis* and *Trichoderma asperellum* boosted TAV plant growth, making it more tolerant to root knot nematodes. Habitat management: Cultivation of *Solanum scabrum* and *Solanum villosum* reduced *Globodera* sp. soil infestation by 80%. Intercropping with *Amaranthus dubius* reduced *Meloidogyne* sp. soil infestation by 90%. Seed treatment: Seed treated with thiamethoxam/difenoconazole or imidacloprid/pencycuron/thiram successfully protected amaranth in the field against *Myzus persicae*.
- **Capacity building.** Twelve MSc and PhDs were trained on TAV IPM research. Thirty extensionists were trained in TAV pest identification and management; 252 TAV growers were trained in IPM.

Ongoing activities:

- **Large-scale production and release of TAV parasitoids and predators.** the parasitoids *C. icipe* and *A. colemani*, and the exotic predatory mite *Phytoseiulus longipes* are mass-produced for release in Kenya and Tanzania.
- **Biopesticides.** Field validation trials of biopesticides are ongoing across TAV production systems in a participatory approach with farmers. We are also assessing the effects of endophytes on inducing systemic resistance to root knot nematodes and potato cyst nematodes, as well as TAV growth promotion under different climate/environmental stresses.
- **Resistant cultivars.** Certified healthy resistant TAV varieties/cultivars against stem weevils and leafwebbers/leafworms have been introduced, promoted and disseminated for sustainable intensification in Kenya and Tanzania through a farmer-participatory approach. Seed distribution pathways in Kenya and Tanzania are being promoted through healthy TAV seed kits.
- **Habitat management.** We are evaluating the efficacy of intercropping of amaranth and African nightshade with other TAVs for managing major above- and below-ground pests and promoting natural enemy populations, in a participatory approach with farmers.
- **Capacity building.** Five MSc students are continuing with their research project activities and learning about agroecological IPM in TAVs ((1) Bretor Mutua: 'Evaluation of potential push-pull plants for the management of above ground pests of crucifers in smallholder production systems', (2) Essy Kipkirui: 'Assessment of farmers knowledge and perception of agroecological approaches in crucifers and traditional African vegetables'; (3) Lyndah Gatwiri: 'Baseline data assessment of belowground pathogens in smallholder crucifers and traditional African vegetables farmer fields'; (4) Byonanebye Alex: 'Efficacy of fungal/endophyte isolates on Alternaria leaf spot of amaranth and temperature dependent immunological responses in the Hawaiian webworm, *Spoladea recurvalis* exposed to these biological control agents'; (5) Druscilla Obonyo: 'Efficacy of endophytic fungus in the management of *Spoladea recurvalis* (Lepidoptera: Crambidae) on amaranth'). In addition, farmers are co-researching, adapting and testing *icipe*'s deployment of TAV parasitoids and predators, biopesticides, resistant cultivars, habitat management.

10.10 Business Development at icipe

Building on our learnings from the current initiatives and recognising the potential commercial opportunities in this venture, we **recommend** that *icipe* develop a dedicated “Business Development” team with the mission to help evaluate the commercialisation of its technologies. The output should be a ‘White paper’ on opportunities and approaches to scaling commercial enterprises using *icipe* technologies.

icipe Management response:

Business Development support at *icipe* is already being offered by the BioInnovate Africa team. Therefore, we do not see a compelling reason to set up a new team except to render the necessary support to Bioresources Innovations Network for Eastern Africa Development Programme (BioInnovate Africa) to do its work.

BioInnovate Africa is a programme of *icipe* that is a regional science and innovation-driven initiative that functions as a bio incubator for biologically based research outputs with commercial prospects (See an example in last year’s [Call](#)). BioInnovate Africa provides grants for commercialising innovative research outputs as well as professional business incubation services. The team has developed the necessary competence for innovation, entrepreneurship, and bioeconomy policy, and works closely with *icipe*’s Technology Transfer Unit and the Social Science and Impact Assessment Unit.

BioInnovate Africa has supported the commercialisation of *icipe*’s biopesticides (*icipe* 7 and 78), hot water treatment technology for pest disinfection and crickets for protein supplementation, together with other non *icipe* based projects that were competitively selected. As indicated in the IPER section on BioInnovate Africa, BioInnovate Africa team has achieved 74% success rate in either market testing or commercial deployment of innovative biologically based products since 2018. Recently (in August 2023), BioInnovate Africa set up a Bio Venture Hub at *icipe* headquarters to encourage entrepreneurial thinking and to transform innovative research outputs into investable packages. The Hub is open to *icipe* scientists, BioInnovate Africa implementing partners and Rsif partners. Presently, BioInnovate Africa team is piloting the Hub’s operations with 4 *icipe* products namely, a) cloud based agrovet for distribution of biocontrol products, b) plant based larvicides, c) cricket protein ingredients, and d) plant derived Methyl Eugenol for control of fruit flies.

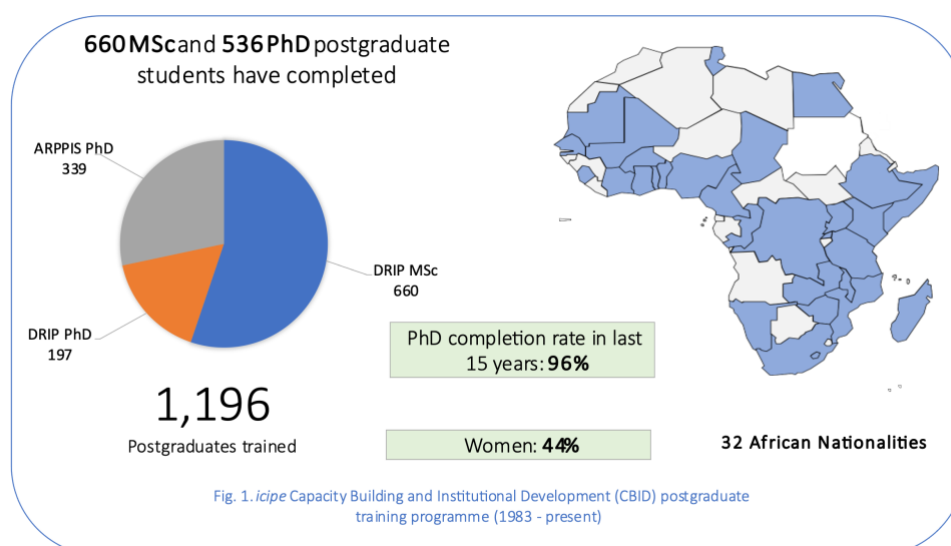
10.11 RSIF: Potential and Limitations

We **suggest**: a) Both the RSIF and CBID programmes take appropriate steps to minimise brain drain of their graduates. b) Should *icipe* continue to host the RSIF programme beyond 2025, it should appoint a new Manager for RSIF.

icipe Management response:

icipe’s capacity building program is designed to generate well-trained, well-rounded and highly qualified scientists who meet the global market demand and are employable anywhere in the world. *icipe* has no authority to determine the choices made by the graduates trained by *icipe*.

icipe’s Capacity Building and Institutional Development (CBID) programme have supported the training of 536 PhD students (339 through the Africa Regional and Postgraduate Programme in Insect Science [ARPPIS] and 197 through its Dissertation research internship programme [DRIP]). The ARPPIS students originated from 32 African countries. In addition, a total of 660 graduates have been trained to date (see Figure below).



Several alumni have risen to senior positions in universities (e.g., Vice Chancellor [VC] or Deputy VC), and others are in policy-influencing positions within governments in different African countries. For example, former ARPPIS graduands including Prof M. Mbugua and Prof. P. Nyeko have all held VC positions in Gulu University in Uganda and Jomo Kenyatta University of Science and Technology in Kenya, respectively. Prof. L. Abubakar and Prof. D. Obeng-Ofori are current VCs at the Technical University of Mombasa, Kenya, and Catholic University College of Ghana, respectively. At *icipe* several alumni have continued their research careers as junior scientists, heads of projects, programmes, units, and research themes (e.g., Prof. B. Torto, Dr S. Ekesi, Dr F. Khamis, Dr. C. Tanga amongst others). A DAAD-commissioned tracer study and information from *icipe* available in the *icipe* student database showed that 75% of all ARPPIS PhD alumni, including alumni from the first intake in 1983, are working across Africa in universities, research institutes, ministries, NGOs and other sectors, where they conduct research, impart knowledge to the next generation of researchers, and contribute to economic development of their countries. *icipe*'s CBID programme therefore has a long-term multiplier effect across Africa by strengthening the research capacity of universities, research institutions, government ministries, policy-making institutions with a reputation as an incubator of some of Africa's best scientists, research leaders and policy makers. These graduates that are predominantly trained in Africa contribute to reducing the brain-drain problem associated with young Africans leaving the continent to study and develop their careers abroad.

Others have taken up international positions, making valid contributions to insect science worldwide. Indeed, whilst emigration of highly skilled *icipe* trained scientists cannot be completely ruled out, the beneficial effects of return migration and global "brain circulation" deserve mention. Several *icipe* trained entomologist have migrated to acquire specific skills at postdoctoral level in advanced laboratories in the global north and returned to Africa serving in various capacities in different research organizations and government institutions. These returnees bring back human, technological, financial and social capital positively contributing to the economic development of their home countries. In few cases where scientists do not return, frequent contacts, sharing of scientific innovations and movements back and forth contribute to growth of African capabilities. A good example is the ARPPIS alumni, Dr Vincent Nyasembe who is currently working for Center for Disease Control (CDC) Foundation in the USA. Although Dr Nyasembe is based in the USA and working for the American government, he is currently implementing projects aim at reducing the burden of malaria amongst smallholder households in Kenya and Tanzania.

Overall, whilst trends in globalization may have increased emigration of highly skill personnels from Africa, scientists trained under the *icipe* CBID PhD programmes with solid entomology background have remained largely in on the continent making solid contribution to the economic development and growth of various African countries. The design and implementation of RSIF is anchored on the strength of *icipe*'s capacity building and the ARPPIS PhD training legacy, and on its strong innovation capability through BioInnovate Africa and other initiatives within the Centre. Since 2018 both CBID and BioInnovate Africa have supported implementation of the RSIF. The two initiatives are complementary.

While it is difficult to predict where the skills developed under RSIF will eventually settle, brain drain is a macro-level problem and *icipe* cannot claim to have exceptional capability to tackle such a multi-faceted problem. Overall, conducive environments for research and development, rapid economic growth in Africa, elimination of turmoil within nations and reducing the income gap between the source and host countries, are crucial to stemming the outflow of skilled professionals. Deliberate intentional efforts by *icipe* include attracting staff-in-training that can easily be re-absorbed into the systems to support the retention efforts. However, the bulk of action for talent retention and sustainability of various training programmes must be strengthened through "ownership" by governments, including development of policies that support retention of trained personnel in African universities and other government institutions.

Currently, the World Bank is supporting implementation of RSIF. This support will end in December 2025. Therefore, continuing to host RSIF beyond 2025 is contingent upon *icipe* receiving the necessary resources to manage the programme. The PASET recently approved a new 10-year strategy, which gives it an executive function of managing programmes like RSIF in the long run. As implementation of the strategy evolves, PASET governance and *icipe* will continue to discuss the future direction of RSIF under *icipe*.

RSIF continues to run smoothly under Dr. Julius Ecuru's leadership. Julius was appointed manager for RSIF in May 2023, when Moses Osiru resigned to take up a new position at the World Bank. He has so far demonstrated his ability to manage the RSIF well. Julius has over 25 years of experience in science, research, and innovation management, 16 of which have been in senior management and leadership positions. Julius has a BSc (Chemistry) Honours and MSc in Environment and Natural Resources from Makerere University, Kampala, and holds a PhD in Technology from the Blekinge Institute of Technology, Sweden. He also has a postgraduate diploma in International Research Ethics from the University of Cape Town, South Africa, and an MBA (Global Business Management) from the United States International University-Africa.

10.12 Extension Beyond East Africa

We **suggest** that, once a country office has been set up, it should be assisted to eventually operate semi-autonomously.

icipe Management response:

Only the Ethiopia country office has been set up as an independent office, enabled by the fact that *icipe* has a hosting agreement with the Government of Ethiopia. Right at the outset, the Ethiopia office was designed to operate in a devolved manner. An assessment was made of the needs at the country office and at the regional offices. An authorisation matrix was established for endorsers and approvers for the acquisition of goods & services and for signatories of bank accounts that were opened both at the country office and regional level. Only significant transactions are approved at the Centre (15% of non-payroll for 2022). In the other countries where *icipe* has set up, in Benin and Uganda, administrative matters are handled through the hosting organization.

10.13 INSEFF-INSEFOODS Collaboration

Because INSEFF and INSEFOODS work in the same area and are located in the same country, we **suggest** that *icipe* considers promoting a synergistic association leading to a collaboration between the two programmes for the mutual benefit of both organisations.

icipe Management response:

icipe's INSEFF Programme over the past 8 years has been successfully engaged with diverse public and private sector partners in Kenya and beyond as detailed below.

Public and private sector partners: INSEFF values partnerships for achieving its larger goals through “One Health” and Circular Economy, scaling edible insect research and its applications for improved and sustainable food systems. Partnerships of INSEFF extend to over 200 public and private sector organisations, spread in 61 countries in 5 continents (Figure 1). INSEFF has impacted more than 6550 direct beneficiaries in Kenya and Uganda alone. It is worth mentioning more than 87 of the 200 partners are in Kenya, including JOOUST through the Africa Center of Excellence in Sustainable Use of Insects as Food and Feeds (INSEFOODS).

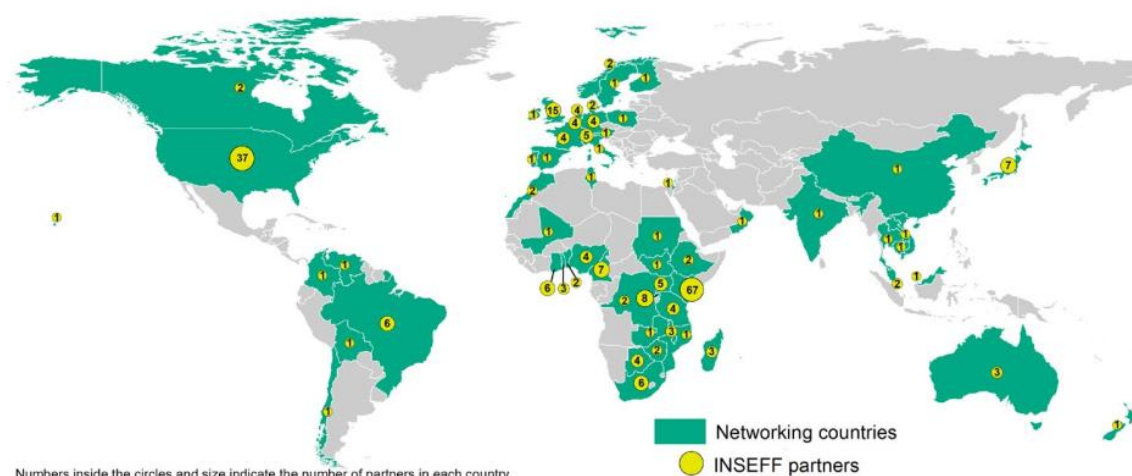


Fig 1: Global partnerships of INSEFF platform.

Building entrepreneurship: In the past eight years, several entrepreneurs have emerged based on INSEFF's insect-based technologies [Prominent insect farming companies in these countries include but are not limited to InsectiPro Ltd (Kenya), Regen Organics (Kenya), Marula proteen Ltd (Uganda), BOBO Eco Farm (Uganda), Biobuu Ltd (Tanzania), BugsLife Ltd (Kenya), Chanzi Ltd (Tanzania), The Bug Picture Ltd (Kenya), EnviBuzz Consule Ltd (Kenya), The Insectary Ltd (Kenya), Riverside Farm Ltd (Kenya), Ecodudu Ltd (Kenya), Protein Kapital Ltd (Uganda), Mana Biosystems Ltd (Kenya), Safe for Health Ltd (Rwanda), and MagoFarm (Rwanda)]. These efforts by INSEFF region have witnessed an increase in BSF production from over 5,000MT to 10,000MT annual production with over 1000 insect-based enterprises making money from insect farming (Tanga et al., 2021).

Partnership with regulatory authorities for facilitating enabling policies for scaling insect-based technologies: INSEFF platform has actively engaged with regulatory and policy organizations in Africa to facilitate the creation of the first standards that allow use of insects in both the food and feed sector in Kenya, Tanzania, Uganda, Rwanda and more recently with regulatory authorities in Ethiopia. Further INSEFF is currently engaged with continental organizations such as the African Regulatory and Standards Organisation and African Union for the harmonization of standards to facilitate scaling policies supporting edible insects and its derived products at the continental level.

Building capacity for research and technology extension for scaling the edible insect sector: Over the years, INSEFF has built research capacity among 6 Postdoc, 8 Ph.D., 41 MSc, and 22 BSc students from 9 countries. *icipe* and partners (i.e., private, and public sector agencies, cooperatives, non-governmental organizations (NGOs), community-based organizations (CBOs) and Universities etc.) have trained over 60,000 people on insect farming.

Turning to the suggestion on strengthening collaboration between *icipe* and JOOUST, the two organisations have been collaborating even before the initiation of the INSEFOODS program and jointly organised the International Conference on Legislation and Policy in the use of Insects as Food and Feed in East Africa in Kisumu in 2016. *icipe* has established an MoU with JOOUST to further research and development efforts around edible insects. Although *icipe* was not actively engaged by JOOUST when the INSEFOOD program was established, *icipe* and JOOUST have jointly trained and supervised several PhD and MSc students recruited through the INSEFOOD program. We are happy to promote synergistic association between the two programmes for mutual benefits, provided there is a strong buy-in, with open and binding contractual engagement from JOOUST and INSEFOOD program.

10.14 Recruitment of Senior Scientists

All research organisations in Africa experience difficulties in recruiting well-qualified, experienced scientists. *icipe* is no exception. A few years back it had considerable difficulty in recruiting the Heads of several of its 4-Health Themes when those retired. A couple of senior scientists, having served *icipe* for several decades and are renowned for their research work, are about to retire this year, and *icipe* will probably face the same challenge.

There is no easy solution to the problem.

icipe Management response:

Qualified staff recruitment is a challenge not just in Africa, but globally. It is more so in insect sciences. A 2018 article in Time Magazine titled “Fewer Scientists Are Studying Insects. Here’s Why That’s So Dangerous” <https://time.com/5144257/fewer-scientists-studying-insects-entomology/> describes the issue. For example, it states that “The CDC, which has about 12,000 employees, has only 13 medical entomologists among its staff.” It further states “The recent emergence of the mosquito borne Zika virus in 2015 has heightened scientists’ concerns. At the start of the Zika epidemic, little was known about the virus’s ability to cause serious medical problems, and the CDC had to perform nearly 200,000 diagnostic tests itself. Amid the already complicated outbreak, a serious gap in the country’s response became clear: There simply were not enough scientists trained in medical entomology available to respond.”

icipe is fortunate to have highly qualified scientists and staff. Among good indicators are the following facts:

- 1) In the last 10 years alone, 261 institutional/individual awards/recognitions have been received (16 institutional, 160 staff, and 85 graduate students.
- 2) In a comprehensive study by Stanford University in the USA in 2021, six of *icipe* scientists ranked in the “World Ranking of Top 2% Scientists” list. The list identifies the top scholars in their own areas of specialty and the frequency with which their publications are cited by other authors around the globe. https://www.researchgate.net/publication/356379232_World_Ranking_of_Top_2_Scientists_in_2021
- 3) 2023 The world's top-cited (2%) scientists released: Seven *icipe* scientists in this list by Elsevier https://elsevier.digitalcommonsdata.com/datasets/btchxktzyw/6?fbclid=IwAR3KT9wcMaH_dmb8114EwxkY4F_AxZJnJq0C8piejZTVvV0V2M7zxfYW1zDw

icipe is tackling the recruitment issue in various ways including recruitment of its former graduates who have moved to Europe with various job opportunities. For example, we have recruited three outstanding former *icipe* students back from Europe (the Netherlands, Czech Republic, Germany) in the last few months alone. *icipe* has long term agreements with IRD and CIRAD, France with secondment arrangements of their scientists who are fully integrated within *icipe* research programs. Other arrangements include the University of New Zealand; CIM - Germany, and NIBIO- Norway. *icipe* is also supporting mid-career scientists to acquire science management/leadership skills.

10.15 Symbiont-based Control of Malaria

We **recommend** that the research on *Microsporidia MB* and malaria, although still at trial stage, be pursued aggressively, with the bulk of the work being done at ITOC, Mbita, supported by advanced testing at the Duduville Campus. Support from international organisations such as WHO should be sought as these technologies enter the field trial stages.

icipe Management response:

The SYMBIOVECTOR programme *Microsporidia MB* research is nearing the end of the first phase, which successfully demonstrated *Plasmodium* transmission blocking under field conditions, efficient horizontal, vertical transmission, and conferral of hosts with a relative fitness advantage. These characteristics could be expected to spread *Microsporidia MB* through host mosquito populations. In addition, the team found that *Microsporidia MB* can naturally reach high prevalence levels likely impeding malaria transmission. Advanced theoretical modelling has demonstrated that strategic releases of *Microsporidia MB* infected mosquitoes could have result in transformative malaria case burden decrease and even, under certain scenarios, eradication. The programme's two primary donors Open Philanthropy and the Bill and Melinda Gates foundation have invited the team to renew their grants for a second phase. The second phase involves extensive semi field testing at Mbita iTOC and will culminate in pilot releases of *Microsporidia MB* in Kenya. One of the likely pilot release sites is Kiamboni island in Lake Victoria near Mbita iTOC. In addition, the SYMBIOVECTOR programme is expanding activities into Rwanda and Ethiopia having established Memoranda of Understanding with government medical research organizations and confirming the presence of *Microsporidia MB* in natural mosquito populations. In phase 2, the SYMBIOVECTOR programme will carry out additional semi-field trials in Rwanda and Ethiopia to demonstrate potential impact of *Microsporidia MB* in different countries and ecological settings. The SYMBIOVECTOR programme is actively engaging additional donors including the Wellcome trust and African governments, as well as stakeholders and policy makers including the World Health Organization VCAG (Vector Control Advisory Group) to which the *Microsporidia MB* based malaria control strategy will be submitted for pre-qualification review.

10.16 Enhancing Public Awareness through a Permanent Educational Exhibit

We **suggest** that *icipe* considers, as part of its public service mission, creating a permanent educational exhibit of insects (for example an "Insect Museum") at its Duduville Campus.

icipe Management response:

We wish to indicate that we have already initiated, almost a year ago, a series on "Insect of the Week" which highlights the interesting nuances of the insect world (<http://www.icipe.org/news/blog>) with online access globally. We are also utilizing this platform as a medium for sharing *icipe*'s research impacts, eg. Series on "Fall armyworm natural enemy of the day" on biological control agents of Fall armyworm during the organisation of the global forum on biological control of fall armyworm (<http://www.icipe.org/Coccygidium-luteum>).

Establishment of a physical museum at *icipe* will only largely be accessed by the people in Kenya. Instead, consideration will be given to expand the above insect series and to establish an online insect museum in the next few years as this will create wider awareness on the impacts of insects on mankind and the need to conserve them (and be much more cost-effective than a physical museum). We will also continue to support and work together with the relevant museums that have the mandate to create awareness on biodiversity in the region. *icipe* is mindful of the utilization of resources, sustainability of programmes and how best to reach more people in an efficient way. Establishing a physical "insect museum" would not be consistent with this approach.

ANNEX 2

icipe Management Response to the icipe Periodic External Review (IPER) 2013–2017 Recommendations

The *icipe* Governing Council (GC) and Management thank the IPER chair and members for their thoughtful review of *icipe*'s research and development (R&D) programmes and management. We found the Review Team's comments on *icipe*'s past performance and future directions both insightful and helpful. We will tackle the recommendations made by the Review Team with diligence. Any differences in tactics, sequence, and in approaches on how to effectively strengthen the areas identified will be explored and the best options adopted.

We are in agreement with the recommendations of the Review Team. A specific response to each recommendation is given below.

1. One Health as an Integrating Paradigm

“As a way of furthering the establishment of the one-health paradigm within the Centre, *icipe* should put in place a range of processes/practices and incentives that encourage projects to take a stronger systems approach in their design.”

icipe Management response:

We agree. *icipe* recognizes the long-term benefit of a One Health approach to society and communities. One Health concept is an integrated work of multiple areas implemented locally, nationally, and regionally to achieve optimal and sustainable health for people, animals, crops and the environment, as the health and the ecological balance of the ecosystem are intricately interconnected. A number of the Sustainable Development Goals (SDGs) can be achieved more effectively with this approach.

As the IPER team has correctly recognized, there is a real funding challenge to One Health projects that combine plant, animal, human and environmental health areas. Most funders, as exemplified in calls for project proposals and target funding to specific R&D areas. Even individual funders that have units that fund human health, agriculture and the environment lack funding mechanisms that integrate their own individual programs that allow funding of integrated programs such as One Health. *icipe* is committed to raising awareness and generating scientific research results and evidence that highlights the benefits of integrated research approaches. For example, in the last five years, *icipe* has clearly demonstrated, through high quality research and publications, the negative impacts of the invasive plant species, *Parthenium hysterophorus* (commonly called “famine weed” or “no crop”), on food security, animal health and human health. In addition, *icipe* is the first organization to demonstrate that the flower nectars of this invasive plant species are particularly attractive to malaria transmitting mosquitoes serving as sugar sources, thus negatively impacting malaria control efforts in Africa in addition to its negative impact on animal and environment health.

icipe flagship Push-Pull Programme is an excellent example of a technology that simultaneously and positively addresses multiple agricultural production and health constraints including pests, parasitic *Striga* weed and other weeds, high quality feed for animals, management of carcinogenic mycotoxins, soil and below ground microbiome diversity and health with significant reductions in agrochemical inputs to protect the environment.

icipe has recently attracted funding for an integrated One Health approach project by The Norwegian Agency for Development Cooperation (Norad). The Norad project addresses human health (by reducing the burden of malaria and emerging infectious diseases), climate change, plant and environment health (by filling critical gaps in knowledge on climate change impact on ecosystem services and invasive pests; and deploying climate-smart technologies to improve food security and systems resilience) and capacity building (to train postgraduate students for leadership in scientific research, development, policy, and technology dissemination). Impact assessment, monitoring and evaluation (M&E) and gender analysis are factored into the programme.

2. Strategic Capacity Needs within an Evolving *icipe*

“Some critical high-level positions remain vacant and there are a number of new science and administrative positions that should be prioritised. Appointments to the Plant Health, Human Health and Environmental Health theme leader positions to round out the full complement of senior leadership positions are considered to be most critical for both the strategic and operational effectiveness of the institute.”

“...the breadth of functions carried out by this small team puts extreme pressure on their time. At least one, and possibly two new senior executive officers' positions to lead the implementation of senior leadership decisions would go some ways in releasing senior management to pursue its higher level functions and further improve the effectiveness of management and administration.”

icipe Management response:

Agreed. *icipe*'s Senior Management composed of just three staff has certainly taken a heavy load of work putting in long working hours during the past five years. Management recognizes that this is not sustainable. Efforts to fill the leadership positions of the Themes will be continued. During the year 2018, interviews have been carried out for all the three vacant theme leader positions. Offers have been made for the Heads of Environmental Health and Plant Health. While mindful of the financial cost to the Centre, other supportive roles will be provided. For example, to ease the workload, in the past year, Management has employed a part-time highly experienced staff member based in the USA who has been providing significant input to proposal development, content writing, and contributing to strategic thinking and directions of the various themes and units of the Centre. This has provided an effective support to Management. In 2018, *icipe* has competitively won major continent-wide initiatives and other funding opportunities, further expanding the Centre's responsibilities and funding pools. These will enable *icipe* to seriously consider and implement these recommendations.

"While *icipe* already has modelling skills in the GIS research unit and within its Themes, it would benefit from stronger modeling capability that would assist to conceptualize, engineer and develop a modelling framework to enable *icipe* to fully explore and benefit from the one-health concept. This will be particularly important in epidemiology and early warning systems."

icipe Management response:

Agreed. We are conscious of the importance of spatial analysis and modeling to R&D activities of the Centre. *icipe* has recently employed an additional experienced modeler/software program developer. While we see this as a step in the right direction, there are plans to further strengthen this area as resources become available.

"The review team considers that expansion of the SSIA unit with new skills in sociology and/or anthropology would be timely to support *icipe* to develop its research on how best to pilot IPM and IVM programs, gain wider community adoption of its technologies, and scale management intensive technologies."

icipe Management response:

Agreed. Integrated Pest Management (IPM) and Integrated Vector Management (IVM) technologies and products are knowledge intensive and adoption of IPM and IVM can be met with challenges. *icipe* has recently recruited a senior gender specialist with expertise in anthropology through The Centre for International Migration and Development (CIM) Program which is jointly run by GIZ and the International Placement Services (ZAV) of the German Federal Employment Agency. The scientist is expected to start at *icipe* in November 2018. In addition, *icipe* has recruited a senior gender specialist with expertise in impact assessment and adoption and entrepreneurship with start date of 1st October 2018.

"The current Biostatistics Unit is under-resourced, especially if meta-analysis of large datasets is to be undertaken. Lack of recognised professionals in this discipline might even represent a reputational risk to the Centre, especially given that human health and disease prevention is a key area of research. Strengthening of the biometrics function should be a priority."

icipe Management response:

Agreed. *icipe* is in the process of recruiting at least one additional biostatistician.

3. Data Management

"*icipe* should, as a matter of urgency, finalise and implement a Data Management Policy that will ensure mechanisms are put in place for centralized archiving and backup of data sets that are well labelled and described, that clear protocols under which those data sets might be accessed by other researchers are clearly defined, and that appropriate resources are assigned to implement the policy."

icipe Management response:

Agreed. As the IPER team has correctly noted, *icipe* has a wide range of excellent examples of data management. *icipe* is committed to integrating these into a centrally coordinated and managed system. The priority placed on policy development in this area attest to the Centre's commitment to drive this agenda forward.

4. Pathways to Impact

"In response to this changing environment, *icipe* should:

- a. Ensure that it builds pathways to impact that specifically include building capacity of development partners. This will enable it to free up its research capability to address emerging constraints to agriculture, livestock, environment and human health. There is an evolving research agenda in the "science of scaling," which could be integrated into

joint work between the SSIA and TT Units, and BioInnovate Africa Programme.”

icipe Management response:

Agreed. *icipe* has been involved in building the capacity of its various development partners including the private sector partners and it will continue to do so. For example, during the review period (2013-2017), *icipe* held more than 290 training courses, workshops and other training events for more than 12,000 research scholars and scientists, research and development (R&D) collaborators, farmers, extension workers, and other stakeholders. In addition, the Push-Pull Programme trained more than 150,000 persons in 2013-2017, including farmers, extension workers, agricultural experts, school pupils and other stakeholders in Kenya, Uganda, Ethiopia, and West and Southern Africa. The creation of the Technology Transfer Unit in 2016 has further intensified this function. *icipe* has also been receiving feedbacks from its development partners on the effectiveness of its products/tools/technologies/management practices and on development of new ones for major emerging issues on the ground.

However, *icipe* recognizes that instilling systemic and systematic change across the board in all value-chain actors is a long-term process with major and relentless action and effort by all stakeholders.

- b. Put even more emphasis on developing innovative impact pathways and, as much as possible, ensure that these pathways are well resourced in terms of *icipe*’s role, the role of relevant partners and appropriate funding. This greater emphasis will ensure that *icipe*’s three recent initiatives to overcome barriers to adoption, viz., the inclusion of a TT Unit, the Bioinnovate Africa Programme, and a growing SSIA Unit have a stronger framework for working together with research Themes to design and pilot the best options for impact.”

icipe Management response:

Agreed. *icipe* has several effective and impactful examples of science translation and adoption. In the last five years, *icipe* has improved its delivery mechanisms and signed agreements with a number of effective development partners and governments for scaling of specific product/technology. It has also improved its adoption tracking systems. For example, in 2017 the Push-Pull technology delivered benefits to 176,000 crop-livestock farmers (1 million people) in 7 African countries directly by *icipe*, and 365,428 farmers (more than 2 million people) through *icipe*’s partners; and has reached 88,217,689 people through independent pathways (*Public Media, Agricultural Shows, Newspapers and Magazine Articles, Television & Radio*). In 2014, *icipe* engaged a media monitoring service that provides daily alerts and quarterly reviews of the Centre’s local, regional and international coverage, potential audience reach and advertising value of publicity. *icipe* will build on these initiatives to ensure continued optimal delivery of its research to maximize impact.

In May 2018, The International Development Innovation Alliance (IDIA), a collaborative platform with the shared goal of “actively promoting and advancing innovation as a means to help achieve sustainable development” and composed of major donors including several *icipe* donors held its annual meeting at *icipe* headquarters in Nairobi, Kenya. IDIA “seeks to stimulate the co-production of public goods that support innovation and, at the country level, hasten the creation of strong ‘innovation ecosystems’, in which favorable policy and regulatory frameworks, open data systems and domestic resourcing come together for innovation to thrive.” *icipe* was invited to participate in this meeting and fully embraces this agenda.

The recent recruitments of gender specialists, Monitoring & Evaluation specialist and other expertise will further help identify adoption barriers and create ways of overcoming these. The MasterCard Foundation- funded major project is also generating lessons on adoptions across the value-chains of adoption of modern beekeeping and silk farming technologies.

5. Operational Modality to Cover the African Mandate Area

“The IPER team feels that *icipe* is now at the point that it would be advantageous to extend the operational modality of country, or more appropriately regional offices in West and Southern Africa, potentially building on the experience with push pull in those regions. To do so, however, will require an upfront strategic investment from core resources.”

icipe Management response:

Agreed. Although *icipe* currently has an extensive range of research and capacity building activities in 40 African countries, its physical presence is limited to Eastern African countries. *icipe* recognizes that its impact and influence can be greatly enhanced by strong physical presences in West and Southern Africa. As the IPER team pointed out this requires long-term funding and commitment.

There is no question that the strategic long-term funders (core donors) namely, UKAid (DFID); Sida, Sweden; SDC, Switzerland; the Kenyan Government; and long-term restricted project donors including Biovision, the European Union, BMZ/GIZ, Germany and DAAD, Germany, among others, have been instrumental in helping build a strong, impactful, transparent and highly competitive *icipe* of today. It is to these funders to whom will turn to in pursuit of

fulfillment of this recommendation. Management cannot emphasize enough the importance of core funding (long-term strategic unrestricted fund) in *icipe*'s operations. It is a fuel for creativity and innovation, program and capacity stability, impact, flexibility to embark on and address new and burning emerging issues such as the recent invasion of Africa by the fall armyworm that has threatened to wipe out all the food security achievements of many years. Without a doubt, core funding is also highly beneficial to the donors themselves as they will achieve their goals more effectively and we believe this extension to other parts of Africa shall also coincide with these goals.

Another driver of *icipe*'s extension will be its involvement on the Regional Scholarship and Innovation Fund (RSIF) programme. *icipe* will complement its efforts with other continent-wide science funding initiatives by African governments such as the Partnership for Skills in Applied Sciences, Engineering and Technology (PASET). African governments and the private sector, with facilitation by the World Bank (WB), launched the PASET initiative in 2013. To achieve its goals, PASET has undertaken several national and regional level activities, of which the RSIF is the flagship initiative. The RSIF's objective is to contribute towards the training of a critical mass of PhD and post-doctoral candidates in Applied Sciences, Engineering and Technology (ASET) fields for priority sectors in Sub-Saharan Africa (SSA) and build the capacity of a core of African universities to train these candidates. The RSIF will also build capacity in the region to sustainably support those PhD graduates beyond their training as they go into academia, industry, or become entrepreneurs through research and innovation grants. The ultimate outcome is for the RSIF to build and increase the R&D workforce for both academia and industry in the SSA region.

icipe has recently been competitively selected and appointed as the Regional Coordinating Unit (RCU) of RSIF with a mandate that includes overall coordination planning, monitoring and evaluation of RSIF activities. Specifically, *icipe* will manage the two RSIF funds; strengthen the capacity of universities and partnering institutions to manage PhD scholarships, and to conduct research and innovation in the priority sectors, which include materials, energy, food security and ICTs. In addition, *icipe* will facilitate the creation of partnerships with governments, universities and national and international research organisations for research training, for example through sandwich training and collaboration with centres of excellence. *icipe* will receive the International Development Association (IDA) grant funds and is expected to coordinate future contributions from governments, the private sector and other sources, administering them under the oversight of the PASET governance bodies.

icipe believes that this opportunity in conjunction with other core resources will enable us to implement this recommendation.

6. Capacity Building, Institutional Development, and Expanded Outreach

"There is an opportunity to use the success of the CBID Programme to support institutional development in an expanded outreach strategy into West and Southern Africa, as discussed in Recommendation 5. This would entail building capability in selected core centres in those regions, what has been termed centres of excellence. It is recommended that 15-25% of the postgraduate intake in each year be quarantined for students from those selected core partner institutes so that over time, these graduates will significantly build the capacity of the Partnering Institutes. This will require funding which targets capacity building in those regions-- often difficult given that donors have specific country priorities."

icipe Management response:

Agreed. This recommendation can be implemented through the RSIF activities. In addition to the descriptions in the response to recommendation 5, the RSIF will commence with committed funds from the World Bank and the Government of South Korea through a 6-year grant of USD 15 million (WB) and USD 9.0 million (S. Korea), respectively. The grant of the World Bank will build *icipe*'s capacity and help grow the fund to at least USD 65 million by 2024, through contributions from African governments, other donors, the private sector and philanthropies. The World Bank component of the grant will support all design and administration costs of RSIF scholarships, research grants and innovation grants. The Governments of Kenya and Rwanda have to date made contributions of USD 2 million and USD 1 million, respectively, while Ethiopia, Senegal, Ivory Coast, Tanzania, Mozambique and Malawi have pledged their financial contributions.

Through the RSIF Program, several African universities will be selected through open competition and these will be used to train doctoral scholars and will also be beneficiaries of research and innovation grants under the programme. The Universities will be partnered with international universities to provide "sandwich" training in PhD and encourage collaboration on research. Innovation grants will enable faculty and researchers to build a strong culture of excellence in research and collaborate with industry and translate outputs of their research into practical uses in society either through existing firms or by starting up new enterprises.

7. Ensuring Financial Sustainability

"Some combination of increasing the number and funding from core donors and improving cost recovery from the grant portfolio with the eventual objective of achieving full cost accounting. Both strategies have their own challenges but the IPER team's rather probabilistic assessment is that any medium-term growth in *icipe* will primarily come from

restricted funding and that this would argue for further movement—acknowledging that the Centre already is moving in that direction—to increased cost recovery and eventually full cost accounting.”

***icipe* Management response:**

Agreed. One of the major tasks of *icipe* Management in the past five years has been the diversification and stability of the funding portfolio. The enhancement of *icipe*'s profile and impact in recent years has helped in achieving this task. This has been achieved in no small measure through media exposure. One key example was *icipe*'s selection and being featured in the new TV series “The Mind of the Universe”, a series established by prominent and award-winning international science journalists and supported by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and others. It is interesting to note that *icipe* is the only organization selected in agriculture globally and in Africa specifically, for effectively and innovatively translating high quality science for the benefit of humanity. Another recent exposure was the selection of the Director General of *icipe*, and *icipe* by extension, by Bill Gates as one of the five ‘Heroes in the Field’ (and the only one in agriculture), and being featured in a video narrated by Bill Gates in person and in his blog, and in a Time magazine article guest edited by Bill Gates. *icipe* today is much more known to the public than five years ago. Some of these highly visible publicities have helped bring financial support from even unusual sources like individuals.

icipe Management believes that the main foundation for creating financial sustainability is continued excellence in scientific outputs and generation of transformative technologies and products that can change livelihoods sustainably and effectively, in addition to prudent and transparent financial management. The recent statement made by Prof. Javier Botero, Lead Education Specialist at the World Bank, sums it up as “*icipe* was awarded the PASET/RSIF grant due to the Centre's strong processes and systems, governance, record of world- class R&D and demonstrated experience in PhD and institutional capacity building in Africa, and its excellent record of research commercialization. Moreover, *icipe*'s extensive network of academic, research, donor and development partners amounting to over 300 organisations and institutions, in Africa and across the world, is a huge asset to the goals of RSIF.”

icipe Management, with strong support of the Governing Council, works to effectively and permanently embed this excellence in research and capacity building, wide-spread impact, transparency and accountability as a culture of *icipe*.

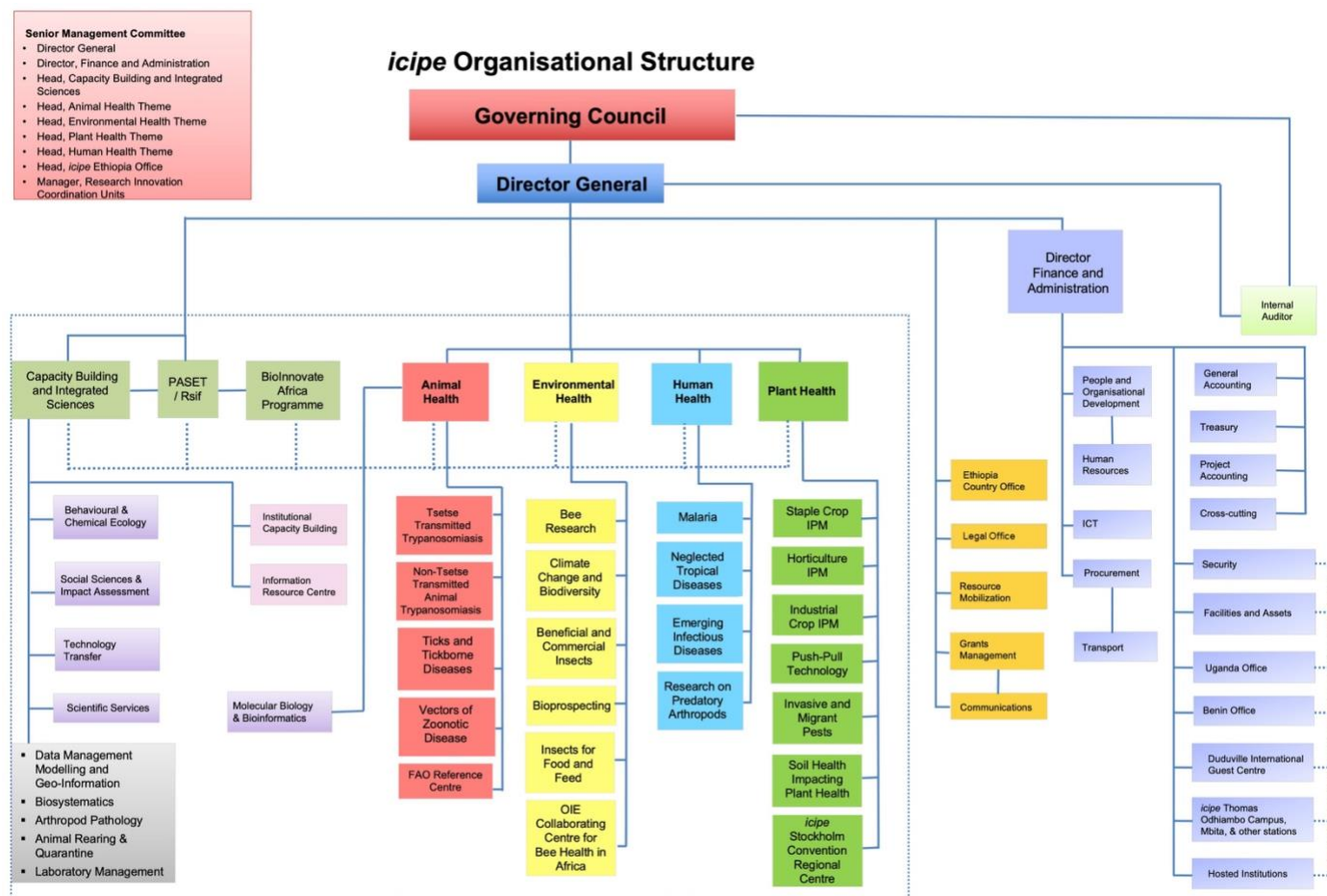
Through the RSIF grant, *icipe* has embarked onto something new. RSIF will operate through a General Fund and a Permanent (Endowment) Fund. The Endowment Fund will ensure sustainability of the fund, and will be professionally and independently managed. *icipe* will further explore this endowment angle for its other operations.

icipe Management has also been working towards full-costing of projects, and improvement of cost recoveries. As clearly noted by the IPER team, Management has also improved its financial management and created efficiency in a number of areas, thus generating high value for money to its investors and stakeholders.

These measures contribute towards partnerships, key of which are with funders, whose objectives align with those of *icipe*, and thus ensure financial flows that sustain the Centre.

ANNEX 3

icipe Organisational Structure



ANNEX 4

2020 SWOT Analysis of icipe

A SWOT analysis of strengths, weaknesses, opportunities, and threats that may affect icipe and its performance

Methodology: This SWOT analysis was developed by a consultant based on their knowledge of *icipe* through membership of the *icipe* periodic external review (IPER) 2018, development of the Vision & Strategy (V&S) 2013-2020 and from a review of various *icipe* documentation. That analysis underwent a cycle of reviews by the internal V&S 2021-2025 committee of senior managers and scientists that were assembled to support the development and writing of the V&S 2021-2025.

Strengths

- *Past and present philosophy and strategy aligns with the UN 2030 Agenda for Sustainable Development with its focus on poverty, hunger, environmental sustainability and partnership.*
- *Strength of leadership, research and support teams.*
- *Based in Africa and perceived as an African institute (cf perceptions re CGIAR centres and AVRDC).*
- *Historically recognised as a significant capacity building hub for Africa that continues to be strengthened.*
- *Developed better support systems over past few years which are critical for institute functionality and efficiency.*
- *Recognised as a valued partner within the East African innovation community.*
- *Possesses research and innovation capacity which is recognised globally.*
- *History of delivery on research projects outputs that is valued.*
- *Trusted and strong relationships with several major donors.*

Weaknesses

- *Perception the Kenyan (and East African) focus is too strong and that icipe has limited capacity to extend its reach across SSA.*
- *Occasionally difficult to attract science leadership in some domains in part due to perceptions of personal safety and security at locations of operation.*
- *Vulnerable to changes in leadership until institute leadership progresses from the current small but effective leadership team to a broader shared responsibility across theme leadership and capacity development components of the institute.*
- *Sustainability of funding stream will remain challenging, especially in accessing core funds that can cement stability and undertake new science enquiries that will underpin icipe's long term research for development future.*
- *Yet to achieve the adoption uptake profile that it might expect across many of its innovations.*
- *Known mainly for push-pull externally and so needs to build strong narratives around other successes/exciting and innovative projects and programs.*
- *Technology transfer at icipe has traditionally been perceived as a linear process; with multi-disciplinary participatory research practices or broader systems research commencing but as yet, only in its infancy in the institute.*

Opportunity

- *Research philosophy recognises the duality of arthropods – some destructive while others provide direct and indirect benefits.*
- *Africa continent has fastest population growth in the world and expected to continue to grow until 2100.*
- *Africa's transition towards 2100 will trigger new challenges and opportunities in human, animal, plant and environmental health, including emergence of an ever-increasing number of invasive species.*
- *Institutional opportunity to consider the concept of invasiveness of pests and weeds in relation of biophysical (why does a pest establish itself? and socio-economic (how did it enter and how did it spread) environments.*

- *Can build on its established reputation for its research for development and capacity building being designed and delivered through a gender lens.*
- *Potential to lead regional and global Climate Change research on monitoring (e.g., environmental monitoring with insects as indicators at regional scale), mitigation (e.g., insects as food and feed alternatives) and adaptation (e.g., health and systems responses to CC).*
- *Strength in key science domains (e.g., physiology and ecology) that can underpin transition towards systems research in agriculture, human health and environmental function, meta-data analysis, early warning systems and responses, and associated policies.*
- *Has commenced a program of building a substantial social science capability to address the challenges adoption and impact.*
- *Established suite of partnerships with universities and other institutes inside and outside Africa.*

Threats

- *Political and security instability in the subregions in which icipe works.*
- *Regional policy changes especially any policy changes that might restrict regional collaboration.*
- *Major donors introduce changes in priorities and policies that negatively impact institutional funding, especially core funding.*
- *Loss of key senior research staff/and institutional leadership would be problematic.*
- *Difficulty of funding for basic research to underpin icipe's future research for development.*
- *Inertia in moving beyond current portfolio and convincingly define, develop and fund new integrated research such as One-Health and PAR.*
- *Expanding beyond East Africa will challenge icipe systems, leadership spread and capacity of the institute to delivery.*
- *Expansion beyond East Africa reduces the investment into the underpinning science and innovations on which icipe applied science is based.*
- *Priority of underpinning research becomes constrained by a few demanding larger contracts (in research and/or capacity building).*

ANNEX 5

Terms of Reference of the Review

2023 External Review of *icipe*'s R & D, Capacity Building and Management Programs

Background and Terms of Reference

BACKGROUND

Established in 1970, the International Centre of Insect Physiology and Ecology (*icipe*) is an intergovernmental, not-for-profit research organization, with a mission to alleviate poverty by ensuring food security, improving health, protecting the environment and building the capacity of researchers and communities across the developing world, through the application of insect sciences. Employing 600 staff, *icipe* is headquartered in Nairobi (Duduville campus), Kenya with outposts in Ethiopia, Uganda, Benin and a major station on the shores of Lake Victoria in western Kenya (*icipe*-Thomas Odhiambo Campus-ITOC). *icipe* has a proud reputation and history of delivering world-quality science that has made crucial contributions to African food and health policies, delivered development outcomes to rural communities, and has been at the forefront of building Africa's biophysical and socioeconomic research capacity. The Centre's research activities span the African continent with partnerships linking research organisations, universities, the private sector, national programs, NGOs and government organizations not only across Africa, but around the globe. *icipe*'s programmes are delivered via four research themes – Animal Health, Human Health, Environment Health, Plant Health as well as a Capacity Building and Institutional Development unit and several special programmes, all of which are supported by several technical units.

icipe considers the regular external and internal monitoring and evaluation of its performance an important activity to regulate both the quality of its research and development and continued relevance to ensure compliance to its mandate and mission. Thus, the Centre undergoes numerous reviews to assess its institutional performance and output. This includes (i) research projects, which have their own mechanisms of review and planning, based on agreements with funding partners, and with close participation of the stakeholders, (ii) through its Sustainable Research Evaluation Systems (SRES) instituted by the Governing Council (GC) it assesses the scientific quality, translation of results into impact, human resources, partnerships, infrastructure, and capacity development of all scientific units to ensure that the scientific level of research remains at an internationally acceptable level and (iii) *icipe* Periodic External Review (IPER) that broadly evaluates institutional mandate and programmatic activities to ensure it meets the development needs of *icipe*'s beneficiary constituency by reducing poverty, improving health, food security and their wellbeing. These reviews are not independent of each other and at the higher-level bullets (i) and (ii) can feed into bullet (iii). Through these periodic monitoring and evaluation exercises, *icipe*'s activities and operations are prioritized and refocused to meet the needs of the beneficiary communities as well as the larger constituency.

From an institutional standpoint, the GC commissions the IPER exercise.

i. Historical Perspective and Modus Operandi to the Review

a) Reviews

Since 1983, the GC has commissioned the IPER, as an instrument to undertake the review of scientific programmes and the administrative and financial management of the centre. The reviews are carried out every 5 or 6 years - the last one covering 2013 – 2017 was undertaken in January – June 2018, the final report of which is available at <http://www.icipe.org/publications/corporate-publications>. Prior to this, the review covering 2008 – 2012 was conducted in January /February 2013 and the previous one for 2002-2007 was conducted during the first half of 2007. The 2013 - 2017 and 2008 – 2012 reviews were Centre-wide assessments, including R4D, capacity and institutional development, management, internal organisation, administration, policies and partnerships of the Centre. However, the 2007 review focussed exclusively on the programmatic and strategic issues, in particular, research and capacity building agenda.

b) Approach

The review team is to be composed of a multidisciplinary group of experts knowledgeable not only in their respective disciplines, but also in the global research agenda on agriculture, human health and the environment and are also conversant with general developmental issues including management and resource mobilization.

The reviewers shall undertake a study of relevant documentation and carry out an assessment of on-going R&D activities and programmes and visit of *icipe*'s field sites and stations. The review mission shall also consult with partners and collaborators. The review period will culminate in the preparation of a detailed report and key recommendations. The senior management team of *icipe* will be given the opportunity to comment on the report and recommendations prior to submission to the GC. The outcome of these reviews shall also cover recommendations on policy guidelines that facilitate the development of vision and strategic documents as well as mid-term plans with clear-cut schedules for implementation.

ii. Terms of Reference for the Institutional Review

a) *Introduction*

icipe's vision and strategy 2021-2025 outlines steps to be taken to provide, through insect science and capacity building, the much-needed solutions for food and nutrition security, good health, improved livelihoods, and sustainable use of natural resources for the people of tropical Africa. The strategy is based on the Centre's '4-H' themes of Human, Animal, Plant and Environmental Health, using a variety of scientific tools, approaches and disciplines, in collaboration with R&D partners as well as institutions of higher learning.

The vision and strategy is conscious of the very dynamic global environment that *icipe* operates in. The strategy recognises that *icipe* has made crucial contributions to African food and health policy by delivering development outcomes to rural economies and remain at the fore-front of building research capacity in insect science. The vision and strategy document also highlights various challenges and opportunities and how the Centre will respond and simultaneously deliver on-the-ground impact including developing solutions that are both systemic and sustainable by integrating key research components among the themes towards the concept of one health, improving and expanding adoption of technologies from its flagships projects, and strengthen its recently established programmatic areas (e.g. insect for food and feed, endosymbiotic research, microbiome research, soil health.), and units (Data Management, Modelling, and Geo-Information (DMMG) Unit, Integrated Sciences), and creating new partnerships with a broader set of respected and like-minded research institutes to ensure its science remain competitive.

A review of the institution's programmatic and institutional agenda is therefore timely to evaluate how *icipe* is re-positioning itself to meet the new challenges and opportunities. Most importantly, IPER should be able to establish how well the programme agenda is in tune with the institutional mandate and to what extent it meets the development needs of its beneficiary constituency through the co-creation of knowledge-based solutions, building capacity of individual researchers and institutions in Africa, contributing to policy development and ultimately, reducing the impact of arthropod pests and vectors and enhancing the role of beneficial insects, both of which have direct bearing on poverty, health, food security and well-being. The review will also serve as the benchmarking function, taking stock of what has been achieved during the reporting period and enabling a more realistic realignment of programme priorities and implementation plans for the next 5-7 years.

The programme and institutional review will be conducted by three Reviewers. Much of the Review will be completed as a desk exercise, with essential team meetings for: the allocation of responsibilities; visits to *icipe* headquarters and selected *icipe* field sites; discussions with *icipe* stakeholders, partners and beneficiaries; and in the writing of the final report.

b) *Strategic and institutional issues to be considered by the review:*

Based on material provided by the Centre, the team will review the impact of *icipe*'s research and capacity building programmes. Then, following consultation with the Centre's stakeholders, and recognising the fundamental comparative advantage of an international centre in being able to work across country borders, and at the same time acknowledging the constraint on resources, the team will examine the trade-offs across strategic dimensions and offer recommendations for the future research planning of its programmes as well as the institutional requirements for doing so. An important consideration in the analysis will be to show how effective *icipe*'s historical perspective and unique evolution as an African institution and its institutional commitment in pursuing a development agenda for the benefit of Africa's poor has been useful in driving and sustaining its research agenda.

The following are the key pointers to the review:

Vision, strategy and priorities

- i. Success in operationalizing the Vision and Strategy 2021-2025 and the continuing relevance of the proposed challenges and opportunities in the light of emerging global issues since the previous review (i.e., for the period 2013-2017).
- ii. Policies, strategic direction and priorities of the Centre and coherence with its mandate.
- iii. Creation of new strategic partnerships and linkages and their role in the implementation of Centre's vision and strategy.

Accomplishment, quality, relevance and impact

- iv. Recent accomplishments of the Centre in its R4D and training of its constituency
- v. Impact of the Centre's work in meeting national and regional development priorities of its African constituency since the last external review (i.e., for the period 2013-2017)
- vi. Innovative programme design, planning, priority setting, science quality management (e.g. peer review, committees) and strengthening research infrastructure to deliver on the institutional mandate
- vii. Rising to the challenges of emerging opportunities and threats

Effectiveness and efficiency of management

- viii. Assessing the present and future capabilities of the Centre's Management and Administration structure, and policies in support of resource mobilization and the delivery of R&D and capacity building
- ix. Assessing the adequacy of resources (financial, human, physical, information) available and the effectiveness and efficiency in their management
- x. Assessing the effectiveness and efficiency of the Centre's partnership arrangement and relationships with relevant stakeholders

iii. Schedule of the Review

Date	Activities
November - December 2022	Internal consultations and identification of process of review.
December 2022	Terms of Reference (ToRs) prepared internally by <i>icipe</i> Management.
January/February 2023	Finalized ToRs sent to the GC Chair for review and comments.
Early- February 2023	Review and approval of ToRs by GC members.
Mid-February 2023	Invitation of proposals for potential Reviewers to be on the Review Panel
End February 2023	Discussions on names of Review Team panel members internally by <i>icipe</i> Management.
Early March 2023	Final selection report for Reviewers shared with <i>icipe</i> Executive Board (ExBo) members
March-April 2023	- ExBo endorses Process and Review Team members. - Review Team Leader consults to discuss forthcoming review with <i>icipe</i> ExBo members, <i>icipe</i> senior management and scientists (optional).
April 2023	- Internal <i>icipe</i> meeting to agree on documentation and review program. - DG's Office liaises with scientists and prepares the desk review information including preparing responses to 2013 – 2017 review recommendations.
End April 2023	Desk study materials shared with Review Team Panel.
May- early June 2023	Reading of review materials.
June-early July 2023	Review mission begins (approx. 10-15 days in Kenya, 3-5 days in Ethiopia and 1-2 days in other African countries with significant programmatic activities of <i>icipe</i>)
July 2023	Finalization of review report in consultation with <i>icipe</i> senior management.
August 2023	Submission of review report to <i>icipe</i> GC.
October 2023	Discussion of IPER at GC meeting.

ANNEX 6

IPER Panel Profiles

Professor Goolam Mohamedbhai – IPER Panel Chair



Prof. Goolam Mohamedbhai, who is a Mauritian citizen, did his undergraduate and postgraduate studies in Civil Engineering at the University of Manchester, UK. He then, in 1972, joined the University of Mauritius as Lecturer where he spent the rest of his academic career. In 1980, he did his postdoctoral research at the University of California, Berkeley under a Fulbright Fellowship. He served as the Vice-Chancellor of the University of Mauritius from 1995 to 2005.

Prof Mohamedbhai was Secretary-General of the Association of African Universities in Accra, Ghana from 2008-2010. He was President of the International Association of Universities from 2004-2008. He has also served on the Council of the Association of Commonwealth Universities for several years and was its chairperson from 2003-2004. He was a member of the Governing Council of the United Nations University, Tokyo, Japan from 2007-2013.

Prof Mohamedbhai now operates as an independent consultant in higher education, with special interest in Africa. He has widely published on the challenges facing African higher education institutions. Currently, he is a member of the Board of the University World News (Africa); the Advisory Council of the US Council for Higher Education Accreditation (CHEA) International Quality Group (CIQG); and the Advisory Board of the Centre for International Higher Education, Boston College, USA. He also chairs the Regional Steering Committee of the World Bank's Project on African Centres of Excellence for Eastern and Southern Africa, as well as the Consultative Advisory Group of the World Bank's Partnership for Applied Sciences, Engineering and Technology (PASET) in Africa project since its inception in 2013.

Prof Mohamedbhai has undertaken consultancies for a number of international organisations and agencies, including Sida of Sweden, the Association of African Universities, the Netherlands Ministry of Foreign Affairs, the Association for the Development of Education in Africa, the Carnegie Foundation of New York, the Leadership Foundation of UK, the World Bank and the German Academic Exchange Service (DAAD).

He is the recipient of the 2009 Symons Award from the Association of Commonwealth Universities for outstanding contribution to the ACU and to Commonwealth universities, as well as the 2014 GUNI-Africa and AfriQAN Distinguished Service to Quality Assurance in Higher Education in Africa Award. He has also been awarded Honorary Doctorates from a couple of universities.

Dr. Felister Wambughu Makini - IPER Panel Member



Dr Felister Wambughu Mvoi Makini holds a BSc in Botany and Chemistry from the University of Nairobi, Kenya, MSc in Plant Pathology from Georgia State University, USA and a PhD in Plant Pathology from the University of Greenwich, UK.

Dr Makini **is a Kenyan citizen and** the Deputy Director General, Crops in the Kenya Agricultural and Livestock Research Organisation (KALRO). She is responsible for crops research that includes technology development and transfer as well as promotion of the establishment and strengthening of strategic partnerships along the research development to utilization continuum and along the agricultural product value chains (APVC). Prior to her current position, she worked as the Deputy Director Outreach and Partnerships in Kenya Agricultural Research Institute (KARI) that is now KALRO after merging KARI, Coffee

Research Foundation, Tea Research Foundation and Kenya Sugar Research Foundation. Before that she was a Centre Director in KARI Kisii. She has won several awards and commendations both in management as having the best managed Centre during her tenure as a Centre Director KARI Kisii and as a scientist. In addition, she received the Presidential Award, the Order of the Grand Warrior (OGW) for her achievements and contribution to society. Together with other scientists, she has won several grants, presented and published several papers and books. She also sits in various boards and committees both national and international.

Prof. Prem Warrior - IPER Panel Member



Prof. Prem Warrior is a US Citizen and currently a Senior Technical Advisor, Valagro S.p.A./Syngenta Biologicals (Part-time) focused on Biologicals R&D and business. He is also undertaking Ag Technology Consultatory/Advisory services for start-ups for Technology, M&A, and Business Development working with Principals and VC/PE firms.

Prof. Warrior is a senior executive with an excellent track record of accomplishment leading people and organizations in the life sciences/agribusiness involving research & development, technology licensing, international business, development of natural products, and global sales management, working in multicultural contexts across for-profit and non-profit sectors in developed and developing countries in the Americas, EU, and APAC. Effective agricultural program development and multi-stakeholder management experience creating global alliances, and partnerships; conceived and launched a legume-agroecosystem program to improve plant/soil nutrition with academic-public-private sector engagement; created and launched a business incubator involving the public and private sector. He has membership and experience in multiple Boards at for-profit and non-profit organizations, with more than thirty-five years of people management experience in leading the discovery and development of commercial products in agriculture.

He has published more than 75 research articles in peer-reviewed international journals and books; 55 international patents granted + approximately 25 patents have been filed and in process, to date; discovered, developed, launched, and helped commercialize at least 6 agri-input products globally; multiple keynote addresses at various national and international technical/business meetings.

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icipe was established in 1970 in direct response to the need for alternative and environmentally friendly pest and vector management strategies. Headquartered in Nairobi, Kenya, *icipe* works through the 4Hs Themes – Human Health, Animal Health, Plant Health and Environmental Health – a holistic and integrated framework aimed to improve the overall well-being of communities in Africa, with sustainable development as its basis.

Our mission is to help alleviate poverty, ensure food security and improve the overall health status of peoples of the tropics, by developing and extending management tools and strategies for harmful and useful arthropods, while preserving the natural resource base through research and capacity building.

Our vision is to pioneer global science in entomology, to improve the well being and resilience of people and the environment to the challenges of a changing world, through innovative and applied research, alongside deep exploratory study, impact assessment, evaluation and sustainable capacity building.

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