icipe's 2021–2025 Results Based Management Framework




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icipe's Results Based Management Framework (2021–2025) **"ROLLING"**

DIRECTOR GENERAL'S OFFICE
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ACRONYMS

4-H	Human Health, Animal Health, Plant Health and Environmental Health
AAS	African Academy of Sciences
AIRCA	Association of International Research and Development Centres for Agriculture
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
AU	African Union
AUDA	African Union Development Agency
CAADP	Comprehensive Africa Agricultural Development Program
CAP	Common African Position
CBID	Capacity Building and Institutional Development
CCARDESA	Centre for Coordination of Agricultural Research and Development for Southern Africa
COMESA	Common Market for Eastern and Southern Africa
CORAF/WECARD	West and Central African Council for Agricultural Research and Development
EAC	East African Community
ECOWAS	Economic Community of West African States
ERP	Enterprise Resource Planning
FAO	Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
GC	Governing Council
ICT	Information and Communication Technology
IDA	International Development Association
IPER	*icipe* Periodic External Review
ITOC	*icipe* Thomas Odhiambo Campus
KPIs	Key Performance Indicators
M&E	Monitoring and Evaluation
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental Organisation
OIE	World Organisation for Animal Health
PASET	Partnership for skills in Applied Sciences, Engineering and Technology
PMEL	Planning, Monitoring, Evaluation and Learning
POPs	Persistent Organic Pollutants
R&D	Research and Development
R4D	Research for Development
RBM	Results Based Management
RCU	Regional Coordination Unit
RSIF	Regional Scholarship and Innovation Fund
SDGs	Sustainable Development Goals
Sida	Swedish International Development Cooperation Agency
SSA	Sub-Saharan Africa
SSIA	Social Science and Impact Assessment
STISA–2024	Science, Technology and Innovation Strategy for Africa 2024
ToC	Theory of Change
TT	Technology Transfer
WHO	World Health Organization

INTRODUCTION

This 2021–2025 Results Based Management (RBM) is based on the Centre's new Vision and Strategy 2021 – 2025 publication - http://www.icipe.org/publications/corporate-publications/vision-and-strategy - which builds on the Centre's achievements and experiences and incorporates the recommendations of the *icipe* Periodic External Review (IPER) held in 2018 - http://www.icipe.org/publications/corporate-publications. The IPER was expansive in its endorsement of what *icipe* has achieved from its research and development (R&D) outcomes and longstanding commitment to capacity building. The reviewers commended the Centre's management and administration and recognized the quality and dedication of its research, capacity building, and support teams. The Centre aims to build on this track record for implementing the new Vision and Strategy. This Results-Based Management (RBM) framework is developed for effective and ambitious deployment of *icipe's* research for development (R4D) capability to mitigate the health, food security and environmental risks faced by people in Africa. It describes how the Centre will explore opportunities for new enterprises that are based on insects and their products and advance discoveries that enable safer and more sustainable solutions to control pests and diseases using new and emerging science disciplines that *icipe* has at hand.

To closely monitor *icipe*'s RBM, in 2018, *icipe* institutionalized its Planning, Monitoring, Evaluation and Learning (PMEL) Strategy. The PMEL Strategy was developed to upgrade *icipe's* existing monitoring and evaluation (M&E) system. The PMEL Strategy provides a framework to guide the prioritization and selection of interventions requiring evaluation and proposes criteria for selecting evaluation designs, methods, and tools.

Established in 1970, *icipe* entered its second 50 years of service as Africa's principal insect and arthropod research institute, in 2020, with the continuing goal of applying the best possible science to overcome the challenges in food and nutrition security, human and environmental health, and capacity building that face the continent's rural and urban communities.

icipe adopted RBM as a project planning and monitoring tool in 2011 and has had RBM framework covering the implementation periods of 2011 to 2013; and 2014 to 2020 - http://www.icipe.org/publications/corporate-publications/results-based-management. These two phases have provided evidence and lessons as an input to implementing the current 2021 – 2025 RBM framework and has offered useful insights for increasing the relevance, efficiency and effectiveness of *icipe*'s further RBM iteration. RBM is first a management system and second, a progress reporting system. RBM is a life-cycle approach to management that integrates strategy, people, resources, processes, and measurements to improve decision-making, transparency, and accountability. RBM is essential for *icipe*'s senior management to exercise sound stewardship in compliance with acceptable performance and accountability standards. The RBM framework helps to track Centre level achievements.

The modern management insists that programs define expected results, focus attention on result achievement, measure performance regularly and objectively, learn from performance information, and adjust to improve efficiency and effectiveness. Ongoing developments in information and communications technology (ICT) have made integrated management information systems possible, opening the door to capturing and processing large amounts of quantitative financial and output data, while analysing it in relationship to qualitative outcome data. RBM is clearly an evolution in management and not a revolution, with origins firmly rooted in the management sciences. These trends have directly influenced research organizations, and *icipe* is no exception. As RBM became more central in program administration across development initiatives, and as RBM was embraced by donor governments, non-governmental organisations (NGOs) and philanthropic organizations, this management approach automatically spilled over into the agricultural research sphere.

In conceptualization of its RBM, *icipe* embraces both accountability and learning as equally important for adaptive management. The RBM framework supports *icipe* to further develop its own internal RBM programme processes, and report on outcomes and impacts from its research as contribution to insect science for development. The RBM is based on its ability to collect, analyse and use massive amounts of data that can be safely stored and easily accessed and sorted out for further analyses. This is doubly the case for *icipe* which works to coordinate efforts of a complex array of projects and programmes and a large number of implementing partners.

The goal of *icipe's* RBM is to strengthen the Centre's vision for RBM best practice, and support the organization to more successfully conceptualize and coordinate the further adaptation and adoption of effective RBM.

The Centre's RBM framework provides guidance to programmes and is intended to help establish organisation-wide standards regarding four main pillars:

1. Defining strategic goals which provide a focus for action;
2. Specifying expected project results which contribute to these goals and align programmes, processes and resources behind them;
3. On-going monitoring and assessment of progress and integrating lessons learned into future planning; and
4. Improving accountability and continuous feedback on progress.

Applying RBM is the beginning of an on-going process to better define the specific goals of *icipe* and to design mechanisms to ensure the measurement of progress towards those goals. At this stage, *icipe* tracks specific performance measures at an institutional level on an annual basis. Projects implemented by *icipe* are the basis of its RBM framework. As such, tracking results begins from a project vantage point. At project level, results are tracked during implementation and evaluated upon project completion. While the tracking tools are utilised during implementation, it is important that the three major phases in a project's evolution are linked and these are: (a) project design; (b) implementation; and (c) impact assessment. Breaking down the project cycle into these three phases, highlights the learning and management aspect of *icipe*'s RBM framework and facilitates in attributing outcomes and impacts to a specific project or a programme.

What is labelled as RBM, and recommended best practice, continues to evolve; and so does *icipe*'s RBM which is ***rolling*** in nature and is updated on an annual basis. While performance measurement of progress toward achievement of expected results remains the core of RBM, complexity acceptance and systems thinking are of greater value than ever. The RBM principles embraced by *icipe* are consistent with established good-practice and help to support project and programme effectiveness, and ultimately, to be valued as a management approach by *icipe*'s stakeholders.

This *icipe* RBM 2021 -2025 aligns with various government priorities where *icipe* operates and provides knowledge-based solutions aimed at equipping the communities in Africa to survive and live within a rapidly changing global environment. The RBM is shaped by the expansion of *icipe's* long commitment to building Africa's research capability and to taking its research findings to users for achieving impact. The strategy aligns *icipe's* effort with global and regional policy initiatives (such as the 2030 Sustainable Development Goals [SDGs] and the Science, Technology and Innovation Strategy for Africa [STISA–2024]) and in doing so, enables the Centre to contribute to the improvement of lives on the continent and around the world.

In light of the global emergence and spread of the coronavirus disease (COVID-19), the *icipe* family, alongside the rest of the world, continues to respond to the emerging reality of the pandemic. The Centre recognises the evolving nature of this threat, and its likely impact across every sphere of society. In spite of the state of affairs, so far, the Centre has continued with its activities albeit in an adapted manner to respond to various requirements to protect health and safety of staff.

2021 – 2025 RESULTS BASED MANAGEMENT OVERVIEW

1. Institutional focus of the Results Based Management Framework

The Institutional focus of *icipe's* RBM remains as stipulated in Centre's **mission** and restated in its **vision** and **mandate**.

icipe is the principal insect and arthropod research centre in Africa and works across the continent through a network of partners from inside and outside Africa, universities, NGOs, and the private sector.

The **mission** of *icipe* 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 **vision** of *icipe* is: "*Pioneering global science in entomology to improve the wellbeing 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"*.

The **mandate** of the Centre as stated in its Charter of 1986 stipulates that "…*the primary mandate of* icipe *shall be research in integrated control methodologies for crop and livestock insect pests and other related arthropods, and insect vectors of tropical diseases and the strengthening of scientific and technological capacities of the developing countries in insect science and its application through training and collaborative work"*.

The year 2020 marked the 50th anniversary of *icipe's* founding. Since 1970, the Centre's achievements have reached many aspects of rural and urban life in Africa. *icipe* has also made a difference in the area of science capability of the region through its significant contribution to building the careers of thousands of staff and students who have worked with the Centre.

Three key elements that are the guiding principles within the scope of *icipe*'s subjects in research and capacity building, define *icipe's* research strategy:

(a) a focus on research domains in which insects and related arthropods have critical roles as disease vectors, pests or are the basis for beneficial uses (such as for food, feed, ecosystem services and value-added products, e.g. silk);
(b) innovation that can be applied to develop sustainable and safe alternatives to reliance on agri-chemicals; and
(c) highly valued Capacity Building and Institutional Development (CBID).

icipe has enacted its **institutional focus** through its skilled and diverse research, capacity building and support teams that are located in three countries (Kenya, Ethiopia and Uganda), an organisational design that incorporates four research themes - Plant, Animal, Human and Environmental Health (4-H) themes, and an array of partnerships with African and non-African universities and research organisations, NGOs and the private sector that encompass a majority of Africa's 55 states.

2. Success in implementing *icipe's* vision and strategy

icipe's R4D approach has remained consistent with its mission, vision and mandate, and operationally it has demonstrated its ability to continue its commitment to long standing challenges across all its four thematic areas. And at the same time the Centre has been responding rapidly to new opportunities and challenges. These include: (i) tackling of emerging invasive pests arriving into Africa; (ii) promoting insects for food and feed for a growing protein economy; (iii) defining the role of microbial symbionts in vector transmission capabilities, nematodes and soil health; and (iii) implementing Bioresources Innovations Network for Eastern Africa Development (BioInnovate Africa, http://bioinnovate-africa.org), Africa's largest regional innovation-driven science initiatives, that began in November 2016. BioInnovate Africa, funded by the Swedish International Development Cooperation Agency (Sida), supports scientists and innovators in the region to link biological based research ideas and technologies to business and the market.

In 2018, *icipe* was competitively selected to serve as the Regional Coordination Unit (RCU) for the Regional Scholarship and Innovation Fund (RSIF), a flagship initiative of the Partnership for skills in Applied Sciences, Engineering and Technology (PASET), with mandate to implement the RSIF Project on behalf of PASET - https://www.rsif-paset.org/. The RSIF aims to address fundamental gaps in skills and knowledge needed for increasing the use of science, technology and innovation for sustained economic growth in sub-Saharan Africa (SSA). RSIF will support doctoral training and post-doctoral research and innovation in selected priority sectors for economic growth and development across SSA. The RSIF priority thematic areas are: (i) ICTs including big data and artificial intelligence; (ii) food security and agribusiness; (iii) climate change; (iv) energy including renewables; and (v) minerals, mining and materials engineering. The Project financing includes a World Bank International Development Association (IDA) grant and support from the Government of Korea and individual African country governments.

All progressive institutes take time to reflect on their progress and reshape their priorities. As part of that regular recalibration, *icipe's* Governing Council initiated an external review (*icipe* Periodic External Review: IPER) in 2018 to evaluate the Centre's research, development and capacity building during the period 2013 - 2017. This review complemented *icipe's* progress in research quality, the impacts it was having on the ground, its network of partnerships, its outstanding achievements in capacity building, and the positive changes implemented in management and governance.

The Panel of reviewers stated that *icipe* has committed to implementing the recommendations of the previous IPER 2007 - 2012. Among these responses have been stronger focus on taking its research to impact through appropriate partners and through building its own capability in key areas. The Social Science and Impact Assessment (SSIA) Unit had been greatly strengthened, and a Technology Transfer (TT) Unit had been created since 2016. Just as importantly, the research team at *icipe* had taken on board the imperative to have their research and innovations taken to communities. There was also significant progress in responding to the recommendations to broaden its influence and impact into other sub-regions of Africa, to put more emphasis on systems research (One Health) and raising the visibility of *icipe* through improved communication, both outside and within the Centre.

The IPER Panel noted that the R&D portfolios of *icipe* include a large number of projects which aim to build incomes and better livelihoods via the direct benefits of insects, such as beekeeping, silkworm farming and more innovative programmes focusing on insects as food and feed, which harness the rapid and efficient growth and reproduction of suitable insect species. R4D continuum constitutes four distinct stages: discovery, proof of concept, piloting, and scaling. Special efforts have been made by the Centre since the past review, with support from some key donors, to improve integration among the 4-H Themes, R&D Units and Programmes, and

for promoting a range of *icipe* technologies, tools and management strategies from discovery and proof of concept to piloting and scaling to deliver on the mandate of the Centre.

As part of the strategy to position the Centre as a key and forward-looking R&D player in agriculture, health and environment, since the past IPER (2007- 2012), *icipe* has accomplished the following:

1. Established a programme on insects for food and feed;
2. Established a research area on symbionts and their role in transmission blockage in vectors;
3. Initiated research on bee microbiota to explore their role in bee health;
4. Established research work on nematodes;
5. Strengthened its SSIA Unit;
6. Created a TT Unit for effective and comprehensive research translation;
7. Created a Communications Unit for reaching a wide audience globally and significantly enhancing the Centre's profile;
8. Succeeded in diversifying and expanding Centre's donor base and corresponding currencies and geography by bringing in 24 new donors;
9. Significantly enhanced its presence and impact in Ethiopia, Somalia and Uganda;
10. Expanded partnerships and regions to further enhance outcomes and impact;
11. Expanded its technologies and products in Southern Africa, Canada and parts of Asia; and
12. Provided hosting services to 14 international and local organisations at the Centre's two campuses (Duduville and ITOC, Mbita).

A key strategy of *icipe* is to remain alert to emerging developmental challenges facing Africa, and to then identify opportunities to use insect science to respond innovatively to such problems. In accordance, the Centre has established itself as a leader in the globally emerging research agenda such as insects for food, feed and other uses. Based on *icipe's* work, Kenya and Uganda have recently become the first African countries to establish official legislation and policy on use of insects as feed.

The IPER 2018 Panel commended *icipe* for using RBM as a performance management tool that provides a framework for assessing results, adapting research programs, and accountability to donors. They noted that it was helping the Centre and its donors to better understand, plan, and report the impact of Centre's work. Implementation of the *icipe's* Vision and Strategy 2013-2020 had resulted in novel solutions for improving food and nutrition security, environmental sustainability, health, youth employment, income generation, private sector development, and capacity building in the target areas. *icipe's* blend of R4D activities that span the spectrum of new discoveries in fundamental science to strategic applications that deliver practical outcomes and these have continued to impact its constituents.

The reviewers also made a series of recommendations as summarised below that are now being incorporated into this RBM 2021 – 2025 and the Vision and Strategy 2021–2025.

The IPER 2018 **recommendations** include:

1. Continued adoption of One Health as an integrating paradigm for the Centre.
2. Appoint strategic new positions and skills that will give *icipe* the enhanced capability to undertake its research and development agenda.
3. Strengthen data management practices to ensure long term data security and its accessibility for new research enquiries.
4. Dedicate more skills and resources to encourage adoption of *icipe's* tools and innovations.
5. Take steps to enable countries beyond East Africa to benefit more from *icipe's* research and development programme.

6. Continue and expand *icipe's* long standing commitment to regional capacity building and institutional development.
7. Ensure financial sustainability by transitioning towards a full cost recovery model.

Notwithstanding the achievements since the last review, *icipe* faces some key challenges as it moves into the next five year period (2021 - 2025). The review team's recommendations reflect what it perceives as the most critical of these. These include placing more emphasis on adopting a systems approach to its research through the One Health integrating paradigm, broadening its influence across SSA, scaling out its technologies, and appointing several new scientists in a number of critical disciplines.

3. Core values that pillar *icipe's* strategic interventions

icipe's core values define who we are and provide the foundation for the Centre. These values are reiterated in the Centre's new Vision and Strategy 2021 – 2025 publication and are based on:

- respectful and inclusive relationships;
- integrity and innovation; and
- accountability and transparency.

Respectful and Inclusive Relationships
icipe strongly believes that its employees are our most valuable asset and is committed to providing a culture of continuous learning for all staff and the tools necessary to foster a high level of expertise and high performance.

icipe values and welcomes a diversity of staff and others, as an organization that is enriched by many perspectives and experiences, sharing of best practices and ensuring equal opportunity to everyone, irrespective of race, age, gender, sexual orientation, status, colour, class, ethnicity, disability, location and religion.

Integrity and Innovation
icipe is committed to treating each other, its partners and others it works with, as valued colleagues, guided by open communication, collaboration, partnership, integrity and respect, in order to achieve our common goals.

icipe serves its clients and stakeholders with passion, sacrifice and courage, aiming to give excluded persons a chance to a decent life and contributing to the betterment of humanity through the power of science.

icipe encourages creativity, reflective thinking, flexibility and adaptability in our approaches to our work, in alignment with our mission to translate research into sustainable public benefits.

Accountability and Transparency
icipe promotes responsible research practices and adherence to sound ethical principles and compliance with standards and regulations; and strives to minimize harm to human health and the environment by introducing and promoting environmentally-friendly technologies.

icipe is accountable and transparent for the effectiveness of its scientific and financial actions at all levels and makes its decisions with openness and honesty.

4. Programme implementation through strategic pan-African and international alliances

As a leader and key Centre for scientific research and innovation in Africa for 50 years, *icipe* has contributed to the delivery of major regional R&D plans, policies and initiatives. Currently, the most pertinent are the 2030 Sustainable Development Goals (SDGs), the African Union's Comprehensive Africa Agricultural Development Program (CAADP), the Science, Technology and Innovation Strategy for Africa 2024 (STISA 2024), and the African Union (AU) Agenda 2063, which continues beyond the SDGs, CAADP and STISA timelines. The AU Agenda 2063 vision is for "*an integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the international arena*". Growth, sustainability, human capital, gender and global partnerships are key aspirations for 2063 and these same attributes are reflected throughout *icipe's* research, innovation and capacity building initiatives.

The 2030 Agenda for Sustainable Development adopted by the United Nations in 2015, contains 17 SDGs. In many respects, *icipe's* work is aligned to all the SDGs, but at its core, contributes directly to SDGs 1, 2, 3, 4, 5, 7, 9, 10, 15 and 17 as evidenced by the research focus on human, plant, animal and environmental health, its sustained and innovative commitment to post graduate education across SSA, and its focus on R4D that provides new employment opportunities and better livelihoods for women and youth. *icipe's* work is also well aligned with the Common African Position (CAP) on the Post 2015 Development Agenda.

In 2014 the African Union, through the New Partnership for Africa's Development (NEPAD) (*now the African Union Development Agency – AUDA-NEPAD*), developed STISA 2024 that illustrates Africa's strategy to place science at the heart of development efforts. The four pillars of action that STISA 2024 targets to achieve its goals are: (1) building and/or upgrading research infrastructures; (2) enhancing professional and technical competencies; (3) promoting entrepreneurship and innovation; and (4) providing an enabling environment for science, technology and innovation development in the African continent. *icipe's* capacity building, research and innovation activities are thus well aligned with continental development aspirations and initiatives.

Some of *icipe's* most crucial actions in support of STISA 2024 are its commitment to capacity building via partnerships with African universities, and provision of high-quality mentoring that lays the foundation for careers, research and tertiary training in Africa. In addition to its roles in postgraduate training, *icipe* provides capacity building in farming and pastoral communities and to health practitioners. *icipe*'s efforts to strengthen capacity are designed to facilitate information flow and uptake of new technologies resulting from its research and innovation. *icipe's* track record in partnering with the private sector to commercialise several of its technologies, including biopesticides and insect attractants and repellents, clearly demonstrates the practicality of translating research into useful products for the benefit of society and alignment of Centre's strategy with CAADP and STISA 2024.

In addition to alignment with overarching regional plans and policies, *icipe* is an active and long-standing partner with some of the most important African regional bodies. These include partnerships with the Forum for Agricultural Research in Africa (FARA), the African Academy of Sciences (AAS), the sub regional economic community organisations (East Africa Community (EAC)), Economic Community of West African States (ECOWAS) and the Common Market for Eastern and Southern Africa(COMESA)) where the focus of the relationships has been on developing harmonised biopesticide and phytosanitary standards and regulations. *icipe* also has close relationships with the three SSA sub-regional agricultural research and development organisations, Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), the West and Central African Council for Agricultural Research and Development (CORAF/WECARD) and the Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA). These regional and sub-regional partnerships along with partnerships with national agriculture and health agencies ensure that partners are aware of

icipe's research outcomes and enable the Centre to be a contributor in establishment of regional policy.

icipe is one of the fifteen regional centres of the Stockholm Convention on Persistent Organic Pollutants (POPs) undertaking capacity building and technology transfer in developing member countries to achieve elimination or reduction of the use of POPs. *icipe* is also designated as a Food and Agriculture Organization of the United Nations (FAO) Reference Centre for vectors and vector-borne animal diseases, a World Organization for Animal Health (OIE) Collaborating Center for Bee Health in Africa, and continues to work closely with the World Health Organization (WHO) and International Atomic Energy Agency (IAEA) to improve national and regional vector control capability and dealing with invasive species across Africa. The Centre is also a founder member of the Association of International Research and Development Centres for Agriculture (AIRCA, www.airca.org), which was stimulated by the need for integrated action to deliver sustainable agricultural intensification at the landscape scale.

5. Institutional responsibility, organisational capability and administrative efficiency

In its drive to modernize *icipe* and enhance accountability, the Centre's management has succeeded in streamlining and highly improving transparency, efficiency, financial management; creating checks and balances in procurement; and in 2015 created an internal audit unit. Over fifteen new policies have been developed and approved by the Governing Council (GC) of *icipe* for improving rules and regulations at Centre level. The income and expenditure data since the last review in 2013, indicate a funding position that is stable and sufficiently diversified. Management closely monitors cost control measures to ensure that the Centre breaks even every year while building up the financial reserves to manage risk and financially buffer the Centre.

icipe Management has also established a currency revaluation reserve as a line item in the financial statements to reduce the risk for the Centre towards currency fluctuations. Despite the challenging global funding environment over the 2013 - 2017 period, *icipe* has been able to maintain its total level of funding. This has been achieved by a balance of ensuring continued support from several of its long-term donors and by attracting new major donors, such as the Mastercard Foundation, and the Government of Norway among others. Achieving this continued level of funding and attracting new donors has been largely enabled by the improved financial, human resources management and control systems as well as the high quality of its research outputs.

icipe management, during 2013 - 2019, developed and implemented a plan to improve infrastructure and to make *icipe* a green Centre by: (i) making the entire campus and its research stations solar powered; (ii) introducing a water conservation system; (iii) implementing energy saving measures; (iv) enhancing landscaping; (v) establishing new buildings for bee research at headquarters and student dormitories at Mbita; (vi) upgrading and renovations of the infrastructure of buildings, labs and field stations (Muhaka, Nguruman, Mbita); (vii) building new insectaries for mosquito and tsetse flies; and (viii) upgrading and modernizing laboratory equipment to strengthen R&D Units.

The Centre has also established infrastructure for videoconferencing to improve internal and external communications; and enhanced computerised business systems and introduced a standardized pre-populated budget template, job application system, travel requisition and staff requisition using an enhanced e-procure system. Building on these initiatives, the Centre has started implementation of an integrated Enterprise Resource Planning (ERP) system. Furthermore, a protected portal on the web for document repository was developed to promote effective Governing Council (GC) communication, proper management and timely distribution of and access to important records and governance documents.

Since the last review, there have also been various changes in staffing at various non-leadership levels to improve capacity and also to better align skills with functions. Management has developed and actualized a staff promotion system for scientists and initiated job classification processes for improved human resource management.

6. Background to development and institutionalization of *icipe's* Results Based Management Framework

icipe's Governing Council (GC) and Management, in 2010, in consultation with core donors, agreed to develop a RBM framework to support the Centre's strategic priorities, policies and guidelines for R&D of insect science. The operational guidelines specifically state that the framework will take into consideration of existing good practices and lay out an approach that: (i) includes measuring results with widely recognised tools; (ii) assesses risk on an ongoing basis; and (iii) incorporates learning into strategies, projects and programmes. The *icipe* RBM adopted in 2011, is an operational framework that for the last ten years has explicitly linked the strategic objectives and priorities of the Centre to the various programmes and projects that it finances so that collectively they help to achieve the goals of *icipe.* A review of *icipe* RBM journey – http://www.icipe.org/publications/corporate-publications/results-based-management - illustrates that management innovation towards a more focused outcomes orientation has had a long history. There has been "home-grown" good practice to support RBM for several years at *icipe* and this is uniquely exemplified in how the Centre has practiced the **ten principles of RBM Best Practice**. These include:

1. ***Results focus*** – *icipe* has maintained a focus on being accountable for achieving results, linked to a compelling vision and strategic framework.
2. ***Consistent leadership*** – *icipe* Senior Management has promoted full engagement in RBM for internal management accountability, learning and decision-making, and for external reporting to stakeholders.
3. ***Commitment to measurement*** – Performance monitoring, focused on measurement using indicators, is at the heart of *icipe's* RBM. The Centre has invested in monitoring and evaluation (M&E) systems as evidenced from its implementation of PMEL Strategy which is led by its Social Science and Impact Assessment (SSIA) Unit.
4. ***Change in organizational culture*** – *icipe* has consciously defined, promoted and supported the RBM culture in a unique way including participatory review and reporting.
5. ***Systems thinking*** – In its annual exercise of RBM reporting and framework updating, the senior management and scientists, evaluate and document connections and synergy across projects, programmes and pathways of change to promote systems thinking.
6. ***Investment in learning*** – Through *icipe's* PMEL Strategy, the Centre has built in regular review and update of performance, assumptions and risk, and expectations, and incorporates the lessons learned in evolving workplans and adaptive use of resources.
7. ***Practical understanding of accountability*** – *icipe* teams are empowered and through their various research projects, these teams do positively influence Centre-wide outcomes and achievements.
8. ***Wide participation*** – All scientists at *icipe* lead in the design of their projects monitoring systems and do participate and support their colleagues in program design and in performance review and adaptation.
9. ***Integration of monitoring and evaluation*** (M&E) – Professional and independent evaluation of *icipe* projects by external assessors is provided for as part of the Centre's RBM approach.
10. ***Investment in information systems*** – *icipe's* RBM is data-heavy. The Centre has invested in the modernization of electronic management information systems that have user-friendly interfaces, and direct alignment with monitoring and evaluation plans, plus training, to support reliability, easy access and efficient utilization. The Centre's new Data Management, Modelling and Geo-Information (DMMG) Unit inaugurated in 2020, is tasked with this responsibility.

Participatory strategic planning is a pre-requisite for effective RBM. At *icipe*, the RBM preparation focuses on the entire programme management cycle and involves three stages:

I. ***Programme Planning***: *icipe* makes plans about the results it will achieve with research funding.
II. ***Programme Monitoring and Reporting***: *icipe* produces the outputs that should generate the expected outcomes (changes) through partnerships.
III. ***Programme Evaluation***: *icipe* demonstrates its results and learns from the experience.

icipe's use of RBM has been very strategic and useful in maximizing project and programme achievements by continuously learning from success as well as failure and making adaptations based on the lessons learned. At *icipe*, this is an annual activity led by the Centre's Director General (DG). To closely monitor *icipe*'s RBM, in 2018, *icipe* institutionalized its Planning, Monitoring, Evaluation and Learning (PMEL) Strategy. The Strategy emphasizes the fostering of stronger partnerships with other local and international institutions with expertise in PMEL. The Strategy is based on a self-assessment of *icipe's* current M&E system by *icipe* scientists and support staff and their shared vision of the M&E system that they would like to see in place by 2025. The evolution of the PMEL Strategy at *icipe* was based on the Centre's RBM.

The PMEL Strategy integrates planning and learning to support adaptive management more effectively. It assumes that *icipe* will achieve its objectives through three interlinked impact pathways, namely: (i) technology development and adoption; (ii) capacity development; and (iii) policy influence. The Strategy has also identified a set of *icipe*-level key performance indicators (KPIs) against which the Centre will assess and demonstrate its aggregate progress towards the three identified impact pathways. The selected thematic KPIs include: (i) contributing to Africa's agricultural transformation through insect science and partnership; (ii) contributing to system capacity development for change; and (iii) influencing the global and regional insect science and policy agenda. Besides the thematic KPIs, *icipe* also has operational KPIs that are important for tracking organisational efficiency, gender inclusiveness, diversity and safeguarding, and for communicating impact.

icipe prides itself on the quality of its insect science research, the technologies it is developing and its role in improving the livelihoods of poor people and environmental sustainability. To this end, the Centre is currently implementing the PMEL system based on its RBM, that enhances project planning, and tracks and measures progress towards outcomes and expected impact (goals). The current M&E system at *icipe* focuses on ensuring compliance between implementing planned activities and work plans, and also ensuring that the financial resources are properly used. The current M&E system at *icipe* requires project leaders to identify anticipated outcomes, impacts, beneficiaries and knowledge dissemination pathways at the planning stage of a project. Based on lessons learnt, the current approach is to direct PMEL at *icipe* through its four principal components. These are: (i) Planning, using a Theory of Change (ToC); (ii) Monitoring/progress tracking; (iii) Evaluation; and (iv) Critical reflection and learning.

Each of *icipe*'s core activity areas has an RBM framework, which constitutes this document. All projects entail knowledge management and learning. The Centre's RBM frameworks of 4-H Themes - Plant, Animal, Human and Environmental Health; and Capacity Building and Institutional Development (CBID) Programme; as well as BioInnovate Africa Programme (since 2017) and the Regional Scholarship and Innovation Fund (RSIF), a flagship initiative of the Partnership for skills in Applied Sciences, Engineering and Technology (PASET) (since 2018), encompass a cycle of planning, periodic performance assessment and organisational learning - all of which are supportive of knowledge creation and sharing. The learning component is critical for identifying and managing risks while bearing in mind the expected results and resource levels. This involves increasing knowledge by learning, knowledge dissemination and feedback into decision making, project design and strategy development.

The intervention logics of *icipe* research, development and capacity building projects, are all of immediate relevance to improving livelihoods and future strategies for contributing to solutions for food insecurity and malnutrition, disease, poverty and environmental degradation. *icipe* is about much more than insects.

2021–2025 *icipe* RESULTS BASED MANAGEMENT FRAMEWORK

PLANT HEALTH at *icipe*

1. Overview of activities

The activities in the Plant Health Theme contribute to improving sustainable food security, nutrition and environmental health through development of integrated pest management (IPM) options that are ecologically sustainable and economically feasible. The Theme aims to discover, develop and pilot technological innovations, products and applications for pest management. Where possible, activities are carried within a multidisciplinary research framework, using a 'one health' concept with active participation of a wide range of partners. All technology development involves farmer participation to ensure farmers' needs are met.

The Plant Health Theme comprises six Flagships: (a) staple crop IPM; (b) horticulture IPM; (c) industrial crop IPM, (d) push-pull technology, (e) invasive and migrant pests, and (f) soil health impacting plant health.

IPM is the key principle that has permeated *icipe*'s plant health research. In IPM, a combination of technologies is used that keep the pest under economic threshold levels while minimizing the use of chemical pesticides. Where possible, priority is given to IPM solutions that minimise the impact on environmental and human health, such as biological control (classical biological control, augmentative biological control including the use of microbial pesticides, and habitat management), the use of semiochemicals, baiting stations, and cultural management strategies. *icipe* is the only international institution in Africa that has an internationally accredited quarantine facility. This enables the Centre to import and maintain exotic natural enemies after regulatory requirements of the Kenyan phytosanitary organisations are approved. For more intractable problems, we aim to undertake an in-depth evaluation of the interactions between soil, plants, pests and natural enemies in their cultivated and natural habitats at a multi-trophic level to develop novel pest management technologies.

The Plant Health Theme participates in technology transfer activities in partnership with national agricultural research organisations (NARS) through training of trainers (ToTs) and other farmer training programmes. Further, the socio-economic impact of introduced technologies and good agricultural practices developed in *icipe*'s Plant Health Flagships are quantified using ex-ante and ex-post impact assessments. Factors associated with the success and failure of technologies are assessed and outcomes utilised for finetuning the technologies for enhanced adoption.

2. Goal and broader objectives

The goal of *icipe*'s Plant Health Theme is to improve plant health benefiting smallholder agriculture, nutrition, health and the environment in Africa, by conducting multidisciplinary research using a one health concept with active participation of a wide range of partners.

The Plant Health Theme will realize its vision by working towards the following strategic objectives across its seven Flagships: (1) to provide leadership in basic and applied research to protect crops against below- and above-ground invertebrate pre- and postharvest pests, both native and invasive, under changing habitats; (2) to realize the benefits from plant-insect interactions by developing IPM options that are ecologically sustainable and economically feasible, with a focus on biological control by harnessing predators, parasitoids, microbes and habitat management strategies; (3) to discover, develop and pilot technological innovations,

products and applications for pest management; (4) to disseminate research results, transfer technologies, influence policies and empower communities through partnerships with national agricultural research organizations, the private sector and other stakeholders; and (5) to build excellence in plant health research in Africa through training of students and scientists.

3. Strategic outlook (2021 to 2025)

a. Staple crop IPM

The fall armyworm, Spodoptera frugiperda: In 2016, the fall armyworm invaded Africa and spread rapidly, emerging as the most serious threat to maize production and food security on the continent. Research focuses on several aspects to manage this new, invasive pest. Regional preparedness and early-warning: Efforts to monitor the fall armyworm are fragmented and awareness on effective, sustainable IPM options in Africa is lacking. There is a need to rapidly enhance awareness and capacity among growers and extension officers for early detection of this pest using available approaches such as pheromone traps. A community-based fall armyworm monitoring network using a mobile application has proved to be an effective tool for regional monitoring of the fall armyworm and will be scaled. Biology and ecology: Environmental conditions in Africa are suitable for the pest to thrive throughout the year although details of the migratory patterns are lacking and will be investigated. The host range of the fall armyworm will be assessed in Africa. Understanding the prevalence of pesticide and transgenic maize resistance alleles in the African population needs to be understood to direct management efforts and develop suitable pheromone blends. Also, establishment of damage levels and yield losses at varying pest densities and at different crop phenological stages, ecologies and soil conditions are critical for determining economic threshold levels. We also envision a long-term survey of the evolution of the interactions between the fall armyworm and maize stemborer communities (two indigenous noctuids, *Busseola fusca* and *Sesamia calamistis*, and one exotic crambid, *Chilo partellus*). After invasion of the fall armyworm, some species of stemborers are expected to shift their distribution by expanding into new areas, while others will shift their habitats and host plant preferences or undergo local extinction. We will develop models on population dynamics that accurately predict pest phenology to adjust control practices and interventions at the right time, taking into account an additional layer of complexity added by climate change.

Management: A coordinated, multi-stakeholder strategy across Africa has been initiated by *icipe* to tackle the fall armyworm menace, aiming to yield a viable IPM strategy in the medium-term based on reliable, scientific knowledge of the pest's taxonomy, ecology and behaviour, and socio-economic impacts. The IPM packages will build on several management strategies, including biological control with biopesticides; habitat management using climate-smart push-pull technology; the use of resistant maize cultivars, hybrids and landraces; and augmentative and conservation biological control using indigenous parasitoids. To ensure effective and wide implementation of the proposed IPM strategies targeting the fall armyworm, *icipe*'s Technology Transfer Unit (TTU) will (1) assess technology needs of the farmers, (2) establish learning and participatory demonstration sites, and (3) validate the technologies with growers and extension agencies. Implementation of technology dissemination will involve diverse partnerships with national agricultural research and extension systems (NARES), non-governmental organizations (NGOs), the private sector, trained lead farmers, local governments and scaling partners. To obtain holistic information on economic impacts of the fall armyworm in Africa, more detailed household surveys that involve large number of farmers are critical, using an economic framework that considers crop yield, value of crops and cost of production. Furthermore, farmers will be trained on 'climate-smart integrated pest management (CSPM)' through learning sites.

Biological control of stemborers: Field maintenance of parasitoids such as *Cotesia flavipes* and *Cotesia sesamiae* released against maize stemborers is challenging. In Kenya, two populations of *C. sesamiae* are present with different levels of *B. fusca* host acceptance. Because host acceptance is heritable, candidate genes involved in host acceptance by the parasitoids can be determined and exploited. Also, the recently described parasitoid *Cotesia*

typhae from Kenya parasitizes *Sesamia nonagrioides* populations and may be used for classical biological control in France.

Postharvest losses of staples and pulses: Postharvest losses of staple cereals and pulses are a serious problem in sub-Saharan Africa, and require technological and organizational solutions. The use of innovative technologies, such as hermetic storage bags, will be adapted by smallholder farmers and widely disseminated against the larger grain borer and other storage pests. Furthermore, research will focus on the link between postharvest insect infestations and contamination with mycotoxins and microbes.

b. Horticulture IPM

Tackling the fruit fly menace to enhance domestic and export horticulture: Tephritid fruit flies are a key menace to horticulture, with both native fruit flies (particularly, *Ceratitis cosyra*, *Ceratitis capitata*, *Ceratitis rosa*, *Ceratitis fasciventris*, *Ceratitis anonae*) and invasive species (*Bactrocera dorsalis*, *Bactrocera zonata*, *Bactrocera latifrons*, *Zeugodacus cucurbitae*) causing high losses in mango, avocado, citrus and cucurbits. Future research to address the fruit fly menace will focus on cutting-edge research on the role of endosymbionts in the management of fruit flies in a tritrophic context as well as their interaction with entomopathogens. In addition, entomopathogens and introduced parasitoids, when used independently, are essential components of IPM programmes of both native and invasive fruit flies, but the compatibility of these biological control agents when used jointly will be assessed. Several entomopathogenic fungal isolates have been commercialized with the private sector for management of fruit flies and other horticultural pests, and there is a need to undertake molecular tracking of these isolates to assess their performance. In addition, the compatibility of these isolates with commercially available male lures and food baits for use in autodissemination devices will be determined. The continent is under constant threat of invasion of new fruit flies, such as *B. zonata* and *Drosophila suzukii*, and current fruit fly IPM strategies need to be finetuned and adopted for the management of these new invaders. The use of push-pull technology using plant-signaling for management of fruit flies will be explored. Moreover, modelling approaches using remote sensing will be essential as part of early-warning systems as well as to guide parasitoid field releases. Host marking pheromones present another formidable tool in the IPM toolbox against fruit flies, as it has great potential for use as an oviposition deterrent. In the last few years, *icipe* has released and evaluated the performance of the parasitoids *Fopius arisanus* and *Diachasmimorpha longicaudata* against *B. dorsalis*, and these releases need to be scaled further to reach larger areas.

Citrus pests and diseases: Citrus greening is currently the most serious and devastating disease threatening citrus production in SSA. African citrus greening is caused by the bacterium Candidatus *Liberibacter africanus* and transmitted by the African citrus psyllid *Trioza erytreae*. However, the recent invasion in Africa by the more serious Asian citrus greening, caused by Candidatus *Liberibacter asiaticus* and its vector the Asian citrus psyllid *Diaphorina citri*, represents an even more serious threat to the citrus industry. The epidemiology of the disease in Africa requires to be unraveled, specifically the role of *T. erytreae* in vectoring C. *L. asiaticus*, the nature of the interaction between the African and Asian insect vectors, the bacteria they vector, and the identity of the C. *L. africanus* complex. Asian citrus greening and its vector *D. citri* are both novel invaders in the African continent, and will require a comprehensive IPM approach comprised of environmentally-friendly pesticides, entomopathogens and classical biological control for the vector. In addition, the role of endosymbionts, semiochemicals and habitat management for both *D. citri* and *T. erytreae* will be explored. The false codling moth is another serious pest of citrus and a cause of stringent export restrictions. Research at *icipe* will centre around developing biological control against the false codling moth on citrus and avocado.

Enhancing tomato production through the management of Tuta absoluta: The recent invasion by the tomato leafminer, a pest of South American origin, causes tomato yield losses of up to 100%. *icipe*, in collaboration with international and national partners, has developed an

IPM toolbox for *T. absoluta*, which is based on mass-trapping with pheromones, use of fungal-based biopesticides, biorationals, host plant resistance, garden sanitation, habitat management and classical biological control. These management strategies are at different developmental stages and need to be further validated, integrated and disseminated to growers. Recently, a colony of *Dolichogenidea gelechiidivoris* was established at *icipe*, awaiting large-scale releases against *T. absoluta*. In collaboration with the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), netting technology will be upscaled and adapted to local conditions.

Thrips: IPM programmes have been developed for thrips based on biopesticides, intercropping and warm water postharvest treatment. *icipe* identified a male-produced aggregation pheromone to which both males and females of *Megalurothrips sjostedti* are attracted, but further studies are required to test the effectiveness of the synthetic compounds under field conditions, identify the most effective release rates and blends, and integrate a product with other IPM tools such as intercropping and biopesticides. The endophyte *Hypocrea lixii* has been developed for use in onions against *Thrips tabaci* and requires large-scale field efficacy testing before commercialization. In addition, research is needed to discover pheromones and kairomones that can be effectively used in IPM programmes against *T. tabaci*.

Postharvest losses: Qualitative and quantitative postharvest losses in horticultural commodities such as mango, bell pepper and French bean as a result of insect pest infestation (fruit fly, false codling moth and thrips) are extensive yet ill-defined. Postharvest treatment of horticultural commodities before export could ensure elimination of invasive pests, satisfying export requirements. Parameters need to be defined for postharvest treatments of these pests. Innovative technologies are required to turn fruit waste, which is currently discarded, into useful organic products such as biofertilizers.

Scaling, adoption and socio-economic impact assessment: In collaboration with national and international partners, *icipe* has developed and is implementing a successful IPM approach against various horticultural pests (e.g. tephritid fruit flies, *T. absoluta*, citrus pests and the diamondback moth *Plutella xylostella*), based on classical biological control using parasitoids, biopesticides, semiochemicals for mass-trapping and monitoring, and good agricultural practices to keep horticultural pests below economic thresholds. These IPM packages need to be implemented on a larger scale and require better integration of biopesticides through combination with semiochemicals or attractants (e.g. through bait-sprays or lure-and-infect devices). Further, the socio-economic and gender impact of IPM interventions in mango and other horticultural value chains need to be better understood. Awareness and capacity at the grassroot level will be strengthened through national and regional networks to implement area-wide management of horticultural pests.

c. Industrial crop IPM

Coffee pests and diseases: Among the most damaging coffee pests and diseases are the coffee berry borer *Hypothenemus hampei*, the black twig borer *Xylosandrus compactus*, the white stem borer *Monochamus leuconotus*, *Hemileia vastatrix* causing coffee leaf rust, *Fusarium xylarioides* causing coffee wilt disease and *Colletotrichum kahawae* causing coffee berry disease. Accurate and real-time distribution maps and models highlighting pest prevalence and abundance are required to estimate their immediate and future risks, and develop IPM packages based on biological control and semiochemicals. In addition, ecological and landscape characterization studies are important to elucidate interactions between coffee diseases with the environment (including the primary and secondary host, other pests and diseases, and shade plants) and to subsequently exploit these interactions to reduce disease prevalence and abundance. Better field trapping systems will be developed for the coffee berry borer. Studies on the biology, ecology and damage of antestia bugs (*Antestiopsis* spp.) will continue. The coffee thrips *Diarthrothrips coffeae*, impacts coffee production especially in the hot and dry season in East Africa. Entomopathogenic nematodes are being explored as potential biocontrol agents for

management of *D. coffeae*. Root-knot nematodes (*Meloidogyne* sp.) are known to heavily impact coffee production and there is a need to initiate surveys and research on these pests.

National coffee value chains and farmers' organizations: Research will focus on sustainable agro-ecological intensification through implementation of IPM options for coffee pests in Eastern Africa, and strengthening of smallholder farming systems through marketing models and incorporation of quality standards. A value chain approach using cooperatives or unions, largely inspired by management practices from the private sector, will be promoted to increase performance of coffee farmers' organizations and to secure sustainable access to the developing quality coffee markets using coffee triple certification (fairtrade, organic and geographical indication) schemes.

d. Push-pull technology

Push-pull technology is a habitat management technology that simultaneously combats stemborers, *S. frugiperda* and *Striga* spp. while improving soil fertility in cereal-livestock farming systems. The technology deploys a stimulo-deterrent tactic in which a legume (*Desmodium* spp.) intercrop acts as a 'push' factor, repelling pests from the cereal crop, and in which the pests are simultaneously 'pulled' to a trap plant, which is planted as a border crop, such as Napier grass or *Brachiaria* spp. Recently, climate-smart push-pull technology was developed using more drought-resilient companion plants.

Expansion and intensification with high-value crops: We will investigate how push-pull technology can be modified to include off-season production of vegetables and other cash crops like cotton and rice, and how push-pull technology can be adapted for medium- and large-scale maize-based farming systems.

Fodder and livestock integration: Napier grass, *Brachiaria* spp. and *Desmodium* spp. are crop components used in push-pull technology and have significant commercial value as livestock fodder. To exploit the commercial potential of fodder plants and use them to fast-track uptake of push-pull technology, there is a need to identify commercialization models that will lead to greater smallholder inclusion, youth employment and women empowerment, and that will yield the greatest revenues for businesses.

Seed quality, affordability and availability: Seeds for climate-smart companion plants are now commercially available through small- and medium-sized seed production companies in Africa, and community-based seed production for second generation push-pull technology will be upscaled. However, germplasm of *Desmodium* spp. and *Brachiaria* spp. that flowers and produces seeds at low latitudes near the equator are not available. The agroclimatic conditions for the best production system, and the economics of *Desmodium* spp. and *Brachiaria* spp. seed production in Africa will be researched.

Impact and adoption: Push-pull technology is knowledge-intensive, and optimal biophysical and socioeconomic conditions and drivers of adoption are only partially understood. By studying optimal drivers of adoption, we can improve and design tailored, efficient and cost-effective impact pathways, with a focus on farmer-to-farm communication (including farmer field days; farmer-teacher models; farmer field schools; the use of mass media; the use of mobile phones; and the use of simplified printed material, participatory videos, drama and cartoon books).

Push-pull technology for the fall armyworm: Climate-smart push-pull technology controls the fall armyworm by repelling gravid female moths. A pull plant for the fall armyworm is not yet known, and new trap plants that can attract both stemborers and the fall armyworm need to be identified. Also, the chemical mechanism of fall armyworm control will be elucidated.

Mycotoxins in push-pull systems: Currently, few effective methodologies exist to reduce aflatoxin contamination in maize. Push-pull technology effectively reduces aflatoxin and

fumonisin contamination of maize, and initial results show that this reduction may be partly caused by reduced insect damage. However, the complete mechanism of aflatoxin and fumonosin control by push-pull technology is not well understood and will be pursued.

Napier stunt disease in push-pull systems: *icipe* has identified five sources of Napier stunt disease-resistant Napier grass germplasm. These materials will be evaluated against Napier stunt disease and their adaptability tested in different agro-ecologies. Various research gaps remain, such as information on disease persistence; genetic profiles of Napier stunt disease, their host plants and their vectors; disease diagnosis; and the effect of the disease on push-pull systems. This knowledge is required to develop Napier stunt disease- and drought-resistant Napier grass cultivars, and to improve on-farm management of this system.

Third generation push-pull technology: Scientists at *icipe* have identified two new *Brachiaria* spp. cultivars 'Xaraes' and 'Piata', which are resistant to red spider mite, more drought-tolerant, more attractive to stemborers and produce more forage biomass. Similarly, two *Desmodium* spp. of African origin (*Desmodium ramossisimum* and *Desmodium incanum*) were identified that are effective against stemborers, *Striga* spp. and the fall armyworm; possess novel root chemistry; are more drought-tolerant; and flower and produce seeds near the equator. However, seeds of these third-generation push-pull companion plants are not yet commercially available, and third generation push-pull technology requires extensive testing under various agro-ecologies.

e. Invasive and migrant pests

Due to climate change and increasing international trade, invasive pests will become a more frequent problem in sub-Saharan Africa. Invasive pests inflict direct economic damage but in addition, many invasive species have quarantine status. Several insect pests of economic importance have recently invaded Africa, such as *S. frugiperda*, potato cyst nematodes (*Globodera* spp.), *Bactrocera* spp. fruit flies, *D. citri*, *T. absoluta* and *D. suzukii*. Some invasive diseases vectored by insects have equally entered Africa. In 2020, countries in the horn of Africa are experiencing catastrophic swarms of the desert locust *Schistocerca gregaria*. Lack of continent- and nationwide surveillance, diagnosis and early-warning systems is a major problem and often results in delayed responses, aggravating the impact of invasive and migrant pest outbreaks. To effectively address invasive and migrant species, a shift in approach from a reactive ad-hoc to a more preventive, coordinated and rapid system-based approach is required, based on a clear contingency plan, and supported by enforceable policies and an inventory of management options. Novel and innovative science-led solutions against invasive and migrant pests are essential, and this is an area in which *icipe*'s Plant Health Theme has continued to excel.

Surveillance, modelling and forecasting, and early-warning systems: For selected invasive and migrant pests, a plant health system will be implemented that is proactive, coordinated and innovative in its approach. Such a system will be built on pro-active surveillance and requires information on pests (e.g., seasonality, distribution, damage), host crops (e.g., alternate hosts, seasonality, distribution) and the environment (e.g., climate data). Parameter gaps will be quantified through research (e.g., lifetables) and surveys. Conventional surveillance protocols such as scouting and the use of pheromone-based traps will be complemented by novel surveillance tools (based on mobile applications, ICT, crowdsourcing and remote sensing). Predictive mathematical, geospatial and remote sensing models will be developed by *icipe*'s Data Management, Modelling and Geo-Information (DMMG) Unit for tracking and monitoring the spread of invasive and migrant pests across Africa and beyond. Such models will also measure the impact of climate change on invasive and migrant pests. These models will be validated and upscaled to other points in time or space. Once developed, these models will guide early-warning systems to monitor invasion, spread and outbreaks of key pests in partnership with national partners. Data mining and machine learning algorithms will be used to analyse available information to provide early-warning alerts to extensionists, phytosanitary officers and policy

makers for informed pest management decisions. Early-warning systems will go hand-in-hand with IPM programmes to proactively address invasive and migrant pests in sub-Saharan Africa.

Desert locust: An increased understanding of desert locust biology and behaviour under a changing climate will lead to targeted and effective management interventions. Biopesticide supply chains will be strengthened and the portfolio of biological control products will be expanded for commercialization by more partners. Studies are required to analyse mechanisms of action and commercialization of known semiochemicals such as phenylacetonitrine, while identifying new semiochemicals such as an egg hatching stimulant and a female sex pheromone. Also, the use of biorationals and novel gene-drive based management tools can equally hold great promise. There is an opportunity for local agribusinesses to develop high-value products based on desert locusts for use in the food and pharmaceutical sectors, and extensive research is required on innovative harvesting techniques, value chain establishment, socio-economics and biosafety aspects.

f. Soil health impacting plant health

Nematodes: Given their economic impact on food production in sub-Saharan Africa, plant-parasitic nematodes require attention, especially root-knot nematodes and potato cyst nematodes. Potato cyst nematodes are recent invasive pests in Kenya, and these are under quarantine due to their serious threat to potato production in other countries. Regional surveys will determine the extent of their distribution and damage. Root-knot nematodes are considered indigenous to Africa and are notoriously difficult to manage due to their broad host range, high reproduction and being ubiquitous in most soils. Upstream research will aim to understand their behaviour and biology, as well as their natural enemies, ultimately leading to improved management strategies. On the other hand, nematodes can be useful as indicators of soil health. We will also evaluate whether push-pull technology has a positive effect on below-ground soil organisms, including beneficial nematodes. Another key research task is to evaluate the biological control potential of entomopathogenic nematodes and elucidate interactions between beneficial soil organisms such as entomopathogenic nematodes and fungi.

Termites and other soil pests: The entomopathogen *Metarhizium brunneum* has been identified as an excellent candidate for termite management. Termites use CO_2 to locate plant roots, and *icipe* has formulated a CO_2-emitting capsule that, when combined with a biopesticide, is highly effective in reducing termite populations. Interactions between semiochemicals, CO_2 and biopesticides will be studied for effective formulation and application strategies against termites and other soil-dwelling insects. Endophyte-based, fungal-based and nematode-based biopesticides will be developed and formulated for sustainable management of termites and other soil pests (the banana weevil *Cosmopolites sordidus*, the sweet potato weevil *Cylas formicarius* and bean maggots) under different cropping systems.

4. Specific future thrusts

Future thrusts in biopesticide research: *icipe* and partners are accelerating R4D efforts into insect symbionts. There is a growing interest towards understanding the role of symbionts in modulating multitrophic interactions between plants, pests and their natural enemies, and exploring their role in biological control. Insect symbionts are known to influence the ability of vectors to transmit plant, human and animal diseases. These relationships can be utilized to develop novel vector and vector-borne disease management strategies, where symbionts can be disseminated into vector populations to limit their capacity to transmit disease. Research is also expanding towards the use of plant endophytes and rhizosphere inhabitants. Their mode of action, systemic induced resistance, provides a new avenue of pest control, especially for cryptic pests such as nematodes and plant diseases. High-throughput screening and bioassays for rapid selection of potent biopesticide strains will be developed. Better understanding of the virulence factors of entomopathogens and identification of corresponding genes can provide gene targets

to develop high-throughput screening procedures of *icipe*'s entomopathogen repository, leading to more rapid and efficient selection of the optimal biopesticide strains. *icipe*'s biopesticide arsenal will also be broadened towards bacterial, and nematode- and virus-based biopesticides. Research will equally be expanded towards pathogens of edible insects. Besides those harmful to the animal or human consuming the insect, a second category of microbes of interest are those harmful to the insect itself. At present, only anecdotal evidence exists of entomopathogens infecting insects during rearing. However, as the insects for food and feed industry takes hold, we expect that entomopathogens will become a problem of large-scale rearing facilities.

Biocontrol Consortium: A Biocontrol Consortium will be established, which links biopesticide companies with a footprint or interest in Africa with *icipe* to fast-track commercialization of *icipe*'s products. Biopesticide companies will benefit from technical training and will have access to advanced research on biopesticides, promising strains and early development of prototype technologies. *icipe* will benefit from data sharing, engage in more efficient and faster scaling and commercialization, and will be informed by the private sector partners on key pests and vectors. Members of the Biocontrol Consortium will act as 'one voice' and inform policy and regulatory bodies on registration requirements and regional harmonization of biopesticide registration.

One Health: Research in the Plant Health Theme cannot be seen in isolation from animal, human and environmental health across landscapes. Increasingly, donors and end users require solutions across landscapes and information on interactions of these solutions. In 2018, scientists from the Plant Health Theme embarked on a novel area of research to integrate pollination services with IPM in avocado and cucurbits. Effectiveness of this integration relies on identification and selection of the right IPM technologies that do not negatively impact pollinators. As another example of a One Health approach, combatting invasive pests requires the use of landscape-based remote sensing data and modelling. Also, the impact of IPM technologies will be measured across landscapes, as resulting reduction in the use of pesticides has major cascading effects on human and animal health.

Climate change: In East Africa, the main consequences predicted by global climate change scenarios include a rise in daily temperature and an increase in rainfall in some parts, while other parts will experience decreased rainfall. Climate change could affect distribution and relationships between crop pests and their natural enemies, and lead to unexpected species interactions, and outbreaks of secondary pests. In addition, novel pests, such as the fall armyworm will continue to emerge. Climate change affects all seven Flagship focus areas of the Plant Health Theme and requires *icip*e scientists to finetune and adapt their technologies, while providing opportunities to mitigate the effects of climate change. We will use predictive models to determine possible effects of climate change on key pests, to characterise and quantify insects' responses to changes in climate, and to develop adaptive responses. We are also embarking on investigating the climate and land cover change impacts on ecosystem services and food security, building capacity and developing adaptation strategies. Through deductive modelling approaches, *icipe* intends to take a leadership role in quantifying the economic injury and yield loss function of insects as a result of rising temperature and CO_2, using stemborers as a model.

Biota for soil health: Reducing soil fertility is a major constraint of agricultural production in sub-Saharan Africa, and greatly affects soil biota. Soil biota play an essential role in ensuring well-functioning of cropping systems. In cereal-legume systems, soil biota greatly influences symbiotic N_2 fixation directly and indirectly (through increase in P availability), soil acidification, and below- and above-ground pest populations. On the other hand, soil biota is positively or negatively influenced by soil properties (chemical and physical), agronomic practices and varieties, and rhizosphere chemistry and microbiome composition, which in turn affect plant growth and defence mechanisms. Recent studies by *icipe* have shown that soil fertility not only affects plant growth and vigour, but also affects pest infestation and damage, as well as the performance of natural enemies. Through close linkages with institutes possessing the necessary expertise in agronomy and soil science, *icipe* will embark on elucidating the soil-plant

health nexus, which will form the basis for innovative soil health management strategies through boosting the health of soil biota.

Economic impact analyses related to plant and environmental health: The ex-ante and ex-post impact assessments of introduced technologies and good agricultural practices developed in *icipe*'s Plant Health Flagships will be analysed to inform policy makers and solicit a wider adoption of IPM practices for improved food safety and security, and market access. Research will also be conducted on the economics of pest management through IPM strategies as well as pesticides, and the interactions with human and environmental health. Economic valuation of ecosystem services and their interaction with human activities will be another area of research.

Gender mainstreaming: *icipe* has prioritized gender mainstreaming with the primary goal of narrowing gender gaps that disadvantage women and youth. Understanding gender roles and enabling environments for women's empowerment along agricultural value chains is critical for the design and dissemination of innovations that equalize opportunities for women and men farmers. Gender-differentiated approaches are central to the realization of equal opportunities for women and men. A critical aspect of gender mainstreaming is the integration of gender at different stages of the research cycle, from research design, implementation to analysis of research outcomes. Equally important is the existence of feedback loops where gender research results are communicated to and taken up by those researchers developing the technologies and by the many partners involved in disseminating the technologies.

Plant Health Results Based Management (RBM) Rolling Framework

Outputs	Outcomes	Performance indicators	Data source	Means of obtaining data	Risks and assumptions
Broad objective 1: Make available IPM options for staple crops by 2025.					
Specific objective: Long-term farming systems comparisons in Kenya and participatory on-farm research of locally adapted technologies for organic agriculture.					
1. Long term experiments (LTE) are well managed based on best management practices feasible for the farmers; good quality agronomic, ecological and economic data are generated; main research findings are disseminated for the academic community, decision makers and sector relevant stakeholders at national and global level.	• Science based know-how on the comparative performance of organic and conventional agricultural production systems in different agro ecological regions in the tropics is made available and taken up by stakeholders.	• Management practices are implemented according to plan. • Yield, and pest and disease incidences are acceptable for well performing farmers. • Verified data on parameters as defined in the country-specific documents are stored in databases. • Soil, plant and input samples. • 8 publications.	• Annual reports. • Annual partners' reports • Databases. • Publication lists. • List of participants at trainings.	• Annual reports. • Small survey with partners. • Databases. • Publication list. • Journal websites. • Training materials and programs of local actors.	• Political, institutional and climatic conditions remain conducive for the conduct of experiments. • Field trials and the quality of data are not severely affected by abiotic or biotic factors. • The stakeholders are interested in the research results. • Project institutions are interested in sharing/demonstrating the results.
2. Innovations addressing bottlenecks of sustainable agricultural production systems are developed through participatory on-farm research (POR) in concert with LTEs and are taken up by local stakeholders; concepts for the future of the project sites are agreed and embedded in the strategies of partner institutions, which are strengthened through empowerment and capacity building within functional networks.	• Sustainable agricultural production systems in project areas are fostered through participatory development of innovations addressing bottlenecks and by improved capacities of partner institutions.	• Technical leaflets, manuals and contributions to relevant events. • Local stakeholders promote the innovations. • Concepts and partners statements/strategies. • Capacity building targeting farmers, research, extension officers and students. • Activities initiated by the networks.	• Annual reports • List of participants to trainings.	• Annual reports and related documents. • Training materials and programs of local actors. • joint concepts. • Participation lists.	• The socio-economic context is conducive for adoption. • Political and economic conditions in the partner countries are favourable. • Strategic and political reasons do not hinder the strengthening and functionality of networks.
Specific objective: A knowledge hub on organic agriculture (OA) established.					
1. Validated technical and methodological knowledge for the promotion of organic agriculture, including processing, is prepared for the context of the participating countries and stakeholder groups,	• 1 compendium/repository of analyzed, validated good organic farming practices is created (database) for each of the participating countries. • 187 technically and methodologically state-of-the-art knowledge products have been created	• 1 compendium in each of the 4 countries. • 100 flyers/factsheets in English and 2 local languages. • 40 videos in 4 local languages (by Access Agriculture).	• Validation reports. • Monitoring reports. • Samples of knowledge products created. • Monitoring and reports by the regional	• Monitoring activities. • Validation activities. • Activity photos. • Mass media publications. • Partner feedback.	• Stakeholders' willingness to share information on ecological organic agriculture compared to conventional agriculture.

and made available through suitable knowledge products.	in suitable formats (flyers/factsheets, videos, radio and TV ads, mobile apps, training modules, etc.) in English and selected local languages of the 4 participating countries. • The East African specific section of the central internet platform for disseminating validated knowledge products has been tested by 3 member organizations in the region, with positive results in terms of its functionality.	• 40 radio or TV ads in 3 Languages (English and 2 local languages) • 3 mobile apps in 1 language (English) • 3 positive tests by participating country partners in East Africa.	knowledge hub and its member organizations. • Status reports and test results of the online platform and its sections, monitoring and reports by the regional hubs.	• Internet platform activities. • User feedback.	• Partnerships are functional and committed towards project objectives.
2. Validated technical and methodological knowledge, strategies and good practices in the field of organic agriculture adapted to the contexts of the countries participating in the Eastern Africa regional knowledge hub, have been disseminated.	• 80% of the individuals registered as multipliers in the regional knowledge hub specifically contribute to the transfer of knowledge on organic production, processing and marketing practices. • The number of trainers trained in organic production, processing and marketing practices and methods has increased by an average of 10% in the 4 countries participating in the East African regional hub. • value chain actors in the 4 participating countries are reached by means of video presentations and radio broadcasts carried out by the regional knowledge hub. An average of 50% of the actors reached are women. • 12 demonstration plots established. • Numbers of farmers reached by OA knowledge disaggregated by women and youth.	• 80% registered multipliers. • 10% trainers trained. • Video presentations with actors (50% women). • Radio broadcast with actors (50% women). • Number of demonstration plots established, • 120,000 beneficiaries reached (50,000 women, 15,000 youth).	• Reports by the regional knowledge hub. • Discussion contributions and experience reports/ • Baseline survey reports of the relevant organizations in the participating countries. • Monitoring and reports by the regional knowledge hub and its member organizations. • Monitoring of participants at information events. • Project reports.	• Monitoring of contributions to knowledge transfer. • Monitoring of the online platform and the posted content. • Demonstrations. • Introduction of practices. • Monitoring of participants for ToT, multipliers and model farmers. • ToT events. • Training workshops for model farmers. • Activity photos.	• Governments and development partners support the organic farming agenda. • Political stability. • Awareness and consciousness of the population for healthy and nutritious products.
Specific objective: Contribute to improve livelihoods and resilience of smallholder farmers in Eastern Africa maize production systems through enhanced preparedness, integrated and eco-friendly management of the invasive fall armyworm (FAW) *Spodoptera frugiperda* for food and nutritional security by 2022.					
1. Regional preparedness, early warning, information on available management options and capacity for timely response to FAW infestation in Eastern Africa enhanced.	• Governments in Eastern Africa and smallholders are prepared to tackle FAW infestation with available and sustainable management options.	• At least 100 extension officers per target country have access to monitoring surveillance tools by 2022. • At least 100,000 maize growers (of which 30% are women) in Kenya, 75,000 in Tanzania, 75,000 in Ethiopia, 20,000 in Rwanda and 20,000 in Uganda have access to monitoring surveillance tools by 2022.	• Program and project reports. • DLCO-EA reports. • FAO FAW framework update reports. • PCPB reports.	• Training workshops. • Farmers' survey. • Secondary data collection.	• Stakeholder willingness to utilize the technologies. • Country regulations are conducive for scaling out technologies. • Dynamic extension systems that will integrate FAW management in their work.

		• By 2020, 1 additional effective FAW IPM option registered and available for commercialization. • At least 3 best-bet cultural practices identified and promoted by 2019.			
2. An effective and sustainable IPM strategy to counter FAW in Eastern Africa developed for dissemination.	• Effective and sustainable IPM strategies suited for different agro-ecologies made available to effectively manage FAW and mitigate losses in Eastern Africa. • Development of sustainable IPM strategies taking into account the interactions between FAW and a community of lepidopteran maize stemborers with their associated parasitoids.	• At least 3 effective and sustainable IPM strategies to counter FAW developed for different agro-ecologies and countries by 2022. • Development of a dynamic simulation model of the interactions between FAW and a community of lepidopteran maize stemborers with their associated parasitoids by 2021. • At least 3 publications highlighting FAW bioecology completed by 2021. • At least 1 effective natural enemy released in 3 target countries by 2020. • At least 100,000 parasitoids released per country by 2022. • At least 2 biocontrol technologies developed by 2020. • At least 25,000 growers in 3 target countries directly benefitting from biocontrol technologies by 2022. • 25,000 maize growers using push-pull for FAW control by 2022. • At least 1 FAW resistant cultivar (or hybrid) availed and disseminated in partnering countries.	• Program and project reports. • Peer-reviewed publications. • M&E reports. • EU reports. • Partner (NGOs, NARI) reports. • *icipe* and CIMMYT reports.	• Laboratory assays. • Field experiments. • Species suitability maps. • Satellite imagery. • Field parasitoid release data. • Farmers' survey. • PhD and MSc studies.	• Political stability in target countries. • IPM for FAW management remains a policy priority in the target countries. • Conducive weather permits biology and ecology studies in the field. • Favourable government policies and regulations for fast-tracking parasitoid introduction, and registering and dissemination of biocontrol agents and biopesticides. • Conducive policy for germplasm exchange, seed production, movement and variety release. • Government and private sector companies willing to invest in IPM tools and options.
3. Implementation of IPM strategy to counter FAW infestation in Eastern Africa jointly with maize crop growers, private sector, NARS, NGOs and growers enhanced.	• Maize growers, private sector, NARS, NGOs and government regulatory authorities in Eastern Africa are widely aware of FAW and its constraints and sustainable FAW-IPM technologies.	• At least 100,000 maize growers in Kenya, 75,000 in Tanzania, 75,000 in Ethiopia, 20,000 in Rwanda and 20,000 in Uganda reached with sustainable FAW-IPM technologies by 2021.	• Program and project reports. • FAO reports. • CABI compendium. • EU reports. • NARS reports.	• Training workshops. • Field days. • Mass media publications. • Peer-reviewed publications. • Farmers' survey.	• Conducive weather permits biology and ecology studies in the field. • Political stability in target countries.

		• At least 40% of the maize production area affected by FAW (341,262 ha) in the target project areas covered by at least 1 effective FAW IPM options by 2022. • At least 3 technologies demonstrations in each country in each year. • At least 1 TV program/Youtube video, 1 radio program and 1 news article per year developed and translated. • At least 5,000 booklets/posters/brochures on FAW developed, printed and distributed each year. • At least 1 FAW microsite developed and maintained.	• MoU documents signed. • Updates, visits, downloads from microsite. • Media outlets, radio programs, TV programs.	• Secondary data collection.	• IPM for FAW management remains a policy priority in the target countries. • Sustained cooperation between partner organizations, NARS, extension networks.
4. Research capacity in Eastern Africa to develop and implement a sustainable IPM strategy for FAW enhanced.	• Stakeholders and researchers in the maize value chain are capable of developing and implementing an sustainable IPM strategy for FAW.	• At least 750 stakeholders trained through ToT events by 2022. • At least 3,000 lead maize growers in each project country participate in technology dissemination activities. • At least 1 Postdoc, and 3 PhD and 5 MSc students trained on FAW research by 2022. • at least 1 open day for policy makers and NARS partners in each year.	• ToT reports. • ToT participants' list. • Project reports. • Theses. • Peer-reviewed publications. • Research data. • NARI & NGO reports.	• Training workshops. • Field days. • Field demonstration activities. • Farmers' survey. • Postdoc, PhD and MSc trainings. • Peer-reviewed publications. • Secondary data collection.	• Stakeholders' willingness and continued participation in training. • Effective linkages with universities.
5. Livelihood, environmental and gender impacts of FAW along the maize value chain in Eastern Africa determined and utilized for decision-making.	• Policy makers, researchers and growers are aware of precise impacts and benefits of FAW IPM interventions in Eastern Africa to facilitate informed decisions.	• At least 150 high-level stakeholders reached per country with FAW evidence data by 2022. • At least 50% of the maize growers to be included in the survey in the target areas aware of the socio-economic benefits of sustainable FAW IPM options.	• *icipe* annual report. • EU reports. • Government reports. • Peer-reviewed publications. • Policy briefs.	• Socio-economic surveys. • Peer-reviewed publications. • Secondary data collection. • PhD training.	• Policymakers, researchers, smallholder farmers and development partners are open to evidence-based research results and recommendations.
Specific objective: Developing, commercializing and upscaling of biopesticides for integrated FAW management to improve the livelihoods of smallholder farmers.					
1. Stakeholders involved in the biopesticide sector including policy makers and regulatory	• Biopesticide stakeholders, regulatory authorities and policy makers sensitized on the	• 1 sensitization workshop for regulatory authorities and policy makers.	• Policy paper on harmonization of	• Policy review, desk research.	• Policy and regulatory authorities' willingness to permit product introduction,

authorities sensitized on policy and regulatory needs and socio-economic aspects related to use of biopesticides for FAW management.	availability of fungal-based biopesticides to tackle FAW in East Africa. • Maize growers, private sector, NARS, government regulatory authorities and policy makers in Eastern Africa are widely aware of FAW and its sustainable management using biopesticides. • Demand and willingness-to-pay for biopesticides for FAW management established. • Harmonization of biopesticides registration guidelines developed and adopted.	• Policy review on regulatory procedures for biopesticides completed and documented. • 1 report on demand for and cost-effectiveness of biopesticides for FAW management. • Combination formulations developed and screened in the laboratory. • Field efficacy of combination products established in multi-country/locational trials. • Potential for 'lure and infect' strategy for FAW in combination with commercial lures initiated. • Registration initiated for commercial biopesticides with proven record in target countries.	biopesticides registration and use. • Report/publication on demand for and ex-ante socio-economic benefits of biopesticides.	• Field demonstrations. • Field days. • Awareness campaign.	field trials and registration of biopesticides in target countries.
2. Label-extension procedures initiated for proven commercially available biopesticides and novel combination formulation product developed and validated in the field.	• Biopesticide registration fast-tracked. and made available to control FAW and mitigate losses and reduce synthetic pesticides use. • Development of new formulations taking into account the interactions between biopesticides and FAW parasitoids,	• Field-efficacy trials with Mazao Tickoff and Mazao Achieve 78, and label extension procedures initiated and accomplished with private sector partners and regulatory authorities • Non-target effects of Tickoff and Achieve on FAW natural enemies assessed. • Commercial biopesticides with proven efficacy introduced in target countries.	• Registration dossiers. • Eco- and mammalian toxicity test reports. • Field efficacy permits.	• Registration dossiers. • Field efficacy permits.	• Regulatory authorities permit product introduction, field trials and registration of biopesticides in target countries. • Favourable weather conditions. • Political stability. • Effective participation of growers and extension officers.
3. Additional novel biopesticide products developed and commercialized through public-private partnerships for FAW management.	• Portfolio of biopesticides against FAW increased and new pathogen isolates identified and characterized. • New biopesticide products developed, registered and commercialized in partnership with the private sector to manage FAW.	• At least 5 novel entomopathogens for FAW management identified and curated. • Protocols for pathogenicity and mass production of potent entomopathogens developed, optimized and communicated to the private sector and community organizations. • Novel formulations of entomopathogens tested and shelf-life and non-target studies initiated.	• Registration dossiers. • Eco- and mammalian toxicity test reports. • Field efficacy permits. • Patents.	• Registration dossiers. • Field efficacy permits. • Patents.	• Private partners find public-private partnerships for FAW management economically viable to invest in the opportunity

		• Eco- and mammalian toxicity for novel formulations generated. • Field efficacy of novel formulations of potent isolates established. • Registration of at least 2 novel biopesticide products initiated.			
4. Capacity of partners strengthened for promoting and scaling the use of biopesticides as important components of FAW IPM.	• Stakeholders and researchers in the maize value chain are capable of developing, implementing, adopting and promoting biopesticides as a sustainable IPM component for FAW management. • Biopesticide use enhanced to reduce synthetic pesticides use for FAW control.	• Training and dissemination materials on biopesticide production and use, and other FAW IPM developed and distributed to reach at least 30,000 maize growers and extension officers in each target country. • Local entrepreneurs trained on biopesticides production through business incubation. • At least 6 participatory field demonstration sites established and awareness on efficacy of biopesticides created among at least 6,000 lead farmers. • Public-private partnerships established for biopesticide production in target countries and commercialization initiated. • Biopesticide use enhanced to contribute to reduction of synthetic pesticide use for FAW control.	• ToT reports. • Project reports. • Theses. • Research data. • Peer-reviewed publications. • Training materials.	• Field demonstrations. • Field days. • ToT participants' list. • Awareness campaign. • MSc theses.	• Stakeholders' willingness and continued participation in training. • Effective linkages with universities.
Specific objective: Enhanced food security, resilience and livelihoods of smallholder maize and tomato farmers through scaling of climate-smart integrated pest management (CSPM) practices and technologies to counter the effects of climate change on pest management by 2022.					
1. Improved knowledge and capacity of farmers, farmer organizations and extension services to implement and policy makers to advocate CSPM technologies to manage pests.	• Provide training to farmers, farmer organizations and extension services to implement and upscale CSPM. • Engage NARES institutions and policy makers working on climate change and agriculture for scaling and advocating CSPM. • Provide support to the private sector to create awareness and deliver CSPM technologies to end-users.	• Capacity of at least 2,100 model female and male farmers built to train other farmers by 2022. • At least 100 farmer-based organizations participate in capacity development for ToT by 2022. • At least 500 female and male agricultural extension agents participate in training on CSPM technologies and their use to train farmers by 2022.	• Training reports. • Project annual reports. • Feedback from project partners.	• Training data.	• Partners commit and adhere to the MOUs/ agreements. • Parasitoids adapt to local conditions. • CSPM technologies and practices are socially and economically acceptable to smallholder farmers. • Value chain actors are proactive to supply CSPM

		• Capacity of at least 20 private sector and civil societies built through training by 2022. • 200 experts from NARES and institutions working on climate change trained on CSPM technologies and mass-rearing of parasitoids to support extension officers by 2022. • 100 policy makers engaged.			technologies and other inputs. • Farmers, farmer-based organizations and extension agents are willing to come and participate in trainings and are committed to train other farmers. • NARES and other institutions get permission and have time to participate in training and project implementation. • Policy makers will find time to be trained and sensitized about CSPM technologies and their impacts. • The private sector has access to technologies and deliver to farmers.
2. Climate-smart pest management technologies integrated, adapted and scaled in Ethiopia and Uganda.	• Strengthen/establish learning sites for scaling CSPM technologies and practices. • Awareness creation and sensitization campaigns organized among stakeholders on CSPM technologies by partners and *icipe* using multiple communication messages and media tailored to a range of stakeholders including religious/public gathering events, existing mobile phone SMS platforms with a free service farmer hotline, policy briefs, field schools, demonstrations, field days/workshops, TV and radio programs, publications and other extension materials. • Awareness creation among youth on pests and CSPM technologies. • Mass-rearing and release of parasitoids for maize stemborers, stemborers and *Tuta absoluta* (~24,000 wasps per week). • Select viable solutions with public and private sector stakeholders to promote partnerships for scaling CSPM. • Strengthen farmers' linkages with CSPM technology providers to facilitate uptake.	• At least 105,000 farmers (~40% women) reached with either of CSPM technologies in both countries by 2022. • Synthetic insecticides use reduced by 30% by 2022. • At least 500 CSPM learning sites established in the target areas by 2022. • 840,000 beneficiaries (farmers, NGOs, private sectors, farmer-based organizations and policy makers) aware of CSPM technologies. • Farmers have access to CSPM technologies and practices through multiple communication strategies including SMS, radio, schools, project meetings, social gatherings, etc. by 2022. • ~24,000 wasps produced per week throughout the project duration.	• Project implementation reports. • Training reports. • Feedback from project partners. • Data from mobile phone application. • Reports from trained scouts. • M&E survey report. • Seasonal field reports. • Feedback from NARS laboratories.	• Mobile phone application data. • M&E survey data. • Field data. • Laboratory data. • Training data.	• Partners commit and adhere to the MOUs/ agreements. • Parasitoids adapted to local conditions. • CSPM technologies and practices are socially and economically acceptable to smallholder farmers. • Value chain actors are proactive to supply CSPM technologies and other inputs. • Partners are willing to take part and join in events organized by the project. • Partners actively engage and commit to scale technologies as per the agreement. • Conducive environment exists for mass-rearing of parasitoids.

	• Monitor and evaluate the uptake of information and CSPM technologies by getting feedback through the mobile phone application.	• 1,500 extension materials distributed by 2022. • 100 secondary and high schools reached by 2022. • 41,500 students and school communities made aware of impact of pests and CSPM technologies. • 1,000 parasitoids per hectare mass produced in local laboratories of NARS in Ethiopia and Uganda. • 65,100 ha of land under maize and tomato systems benefit from the release of parasitoids for key pest species by 2022. • At least 100 private-public sector organizations/ institutions/societies involved in assessing the feasibility of parasitoid mass-rearing with the perspective of long-term industrial production and commercialization. • Level of linkages between farmers and private-public sector improved. • 200 mobile phones are made available to role model farmers (champions).			• Partners have capacity to effectively rear parasitoids. • Local government regulatory bodies and partners are proactive to facilitate granting of parasitoid import permit in time. • Schools collaborate to sensitize students and teachers on pests and CSPM technologies and practices. • NARS partners manage the laboratories and colonies in a sustainable manner to efficiently produce the required number of parasitoids for releases. • Private sector demonstrates willingness to participate in mass-rearing and commercialization of parasitoids. • Farmers and private-public partners are willing to cooperate in delivering the technologies.
3. Existing insect pest monitoring networks improved and strengthened to support risk prevention and rapid response.	• Strengthen existing community-based pest monitoring system networks through the use of semio-chemical traps, training of scouts in selected villages and the use of mobile phone applications. • Strengthen access to downscaled climate projections and remote sensing data for the NARES and policy makers.	• At least 1 best existing pest monitoring system improved by 2020. • At least 20 scouts involved in carrying out pest surveillance by 2022. • At least 180 voluntary farmers participate in pest scouting by 2022. • 20 scouts trained on collecting pest data using mobile applications by 2022.	• Project implementation reports. • Feedback from project partners. • Data from mobile phone application. • Reports from trained scouts. • Training reports. • Project annual reports.	• Field data. • Mobile phone application data. • Training data.	• Partners commit and adhere to the MOUs/ agreements. • Parasitoids adapt to local conditions. • CSPM technologies and practices are socially and economically acceptable to smallholder farmers. • Value chain actors are proactive to supply CSPM technologies and other inputs.

		• 180 voluntary farmers trained and participate in pest scouting by 2022. • By 2022, at least 20 community-based systems for pest monitoring established. • At least 10 NARES have improved access to climate projection and remote sensing database by 2022.			• Farmers are willing to participate in pest scouting. • Scouts collect data as per training provided to them. • NARS have the interest and capacity to use the available databases.
4. Impact of and barriers to scaling of CSPM technologies and practices determined.	• Identification of barriers and opportunities to scale CSPM technologies through a value chain analysis. • Generate and document evidence on the benefits of CSPM technologies, practices and services to foster a learning environment and further strengthen the scaling processes in other countries.	• A working paper on barriers and opportunities to upscale CSPM technologies produced and shared with partners by 2020. • Data on socio-economic analysis of CSPM technologies and impacts of key pests available by mid-2022. • At least 2 papers documenting benefits of CSPM technologies produced by mid-2022.	• Reports from partners. • M&E survey data. • Project implementation reports.	• M&E data. • Field data.	• Partners commit and adhere to the MOUs/ agreements. • Parasitoids adapt to local conditions. • CSPM technologies and practices are socially and economically acceptable to smallholder farmers. • Value chain actors are proactive to supply CSPM technologies and other inputs. • Data of sufficient quality collected on time and participating farmers and other actors cooperate in providing the necessary information through in-person surveys. • Capacity of national country teams sufficient for timely completion of surveys. • Political and security conditions will allow collection of household surveys and secondary data in all countries.
Specific objective: Joint action to develop biocontrol methods against the invasive FAW in Africa.					
1. Productive research links between the Swedish University of Agricultural Sciences (SLU) and	• Active research collaboration between SLU and *icipe* formed, developing innovative and sustainable FAW control methods.	• Number of joint research proposals and scientific publications.	• Project and institutional progress reports.	• *icipe* and partners' annual reports.	• Continued interested and willingness for mutually beneficial and productive research collaboration

icipe for FAW management established.		• Number of collaborative research undertakings. • Knowledge and experience sharing visits and workshops.			between researchers and partner institutes. • Continued research funding.
2. Preference and performance FAW and FAW parasitoids on different host plant species determined.	• Influence of different host plant species on FAW development and parasitism rates determined by 2023.	• Number of peer-reviewed publications on host suitability.	• Research data. • Research publications. • Student theses.	• Laboratory bioassays. • Field trials.	• Minimal disruptions from biophysical and environmental catastrophes.
3. Competition with other Lepidoptera stemborer pest species determined.	• Inter species competition between FAW and stemborer species determined by 2023.	• Number of peer-reviewed publications.	• Research data. • Research publications.	• Laboratory and screenhouse trials	• Continued funding and conducive working environment.
Specific objective: Reinforcing and expanding the community-based FAW monitoring, forecasting for early warning and timely management to protect food security and improve livelihoods of vulnerable communities.					
1. Information generated by CBFAMFEW modeled and used for technology upscaling.	• Build capacity of communities for increased awareness, preparedness and decision-making.	• Number of people trained in FAW IPM. • Number and percentage of hectares protected against FAW. • Number and percentage of people practicing appropriate FAW management practices. • Percent of maize postharvest loss reduced. • Percentage of people trained who retain skills and knowledge after 2 months. • Percentage of attendees at joint planning meetings who are from the local community,	• Monitoring records. • Field assessment and/or survey data. • Kenya Government data. • Project records. • Baseline data. • Beneficiary lists. • Records of land areas planted with specific crops, records of usual (anticipated) harvest yields of the crop plants per unit of land area. • Maps, GPS perimeter walks. • Training participant records. • Meeting participant records.	• *icipe* and NARS partners. • M&E report.	• Conducive weather and political conditions permit field activities. • Sustained cooperation between partner organization, NARS and extension networks. • Partners' willingness to collaborate. • COVID-19 and prevention measures applied.
2. Environmentally friendly FAW IPM tools scaled up in partnership with national partners supported by FAW monitoring and prediction initiatives.	• Reduced pests and pesticides.	• Number of months of household food self-sufficiency on maize as a result of improved agricultural production programming. • Number of people directly benefiting from improving agricultural production and/or food security activities.	• Beneficiary lists. • Assessment and/or survey data • Routine monitoring and project records • Maps, GPS perimeter walks. • Meeting participant records.	• *icipe* and NARS partners. • M&E report.	• Conducive weather and political conditions permit field activities. • Sustained cooperation between partner organization, NARS and extension networks. • Partners' willingness to collaborate.

		• Number of hectares of maize under improved agricultural methods.			• COVID-19 and prevention measures applied.
3. Capacity to scale management options and implementation of sustainable FAW IPM enhanced.	• Improving agricultural production and food security.	• Number of people participating in project training. • Percentage of households with access to sufficient maize seed to plant.	• Event reports. • Meeting participant records. • Project records. • Government (national or local) records.	• *icipe* and partners (NARS) • M&E report • Partnering universities and NGOs.	• Conducive weather and political conditions permit field activities. • Sustained cooperation between partner organization, NARS and extension networks. • Partners' willingness to collaborate. • COVID-19 and prevention measures applied.
4. Coordination, M&E and Impact assessment.	• Build capacity of communities for increased awareness, preparedness and decision-making. • Global advocacy and engagement. • Public-private partnerships.	• Number of people participating in project training/ • Percentage of people trained who retain skills and knowledge after 2 months/ • Percentage of attendees at joint planning meetings who are from the local community/ • Number of people trained in FAW preparedness, risk reduction and management/ • Percentage of people trained on FAMEWS. • Number of students (MSc and PhD) trained. • Number of jointly organized events held. • Number of private sector businesses directly engaged in FAW response as a result of the program. • Total number of individuals indirectly benefiting from FAW IPM program activities. • Number of government disaster contingency plans that incorporate private sector aspects as a result of the program.	• Survey and/or assessment results and project records. • Assessments/surveys. • Market assessments. • Assessments/surveys of beneficiary businesses. • Official government (national or local) documents.	• *icipe* and NARS partners. • M&E report. • Meeting reports.	• Conducive weather and political conditions permit field activities. • Sustained cooperation between partner organization, NARS and extension networks. • Partners' willingness to collaborate. • COVID-19 and prevention measures applied.

Specific objective: Develop an integrated digital tool for Integrated Pest Management through the program Malawi Digital Plant Health Service (MaDiPHS).					
1. To develop models using weather, host plant, pest/disease (including weeds) and edaphic data for integration in digital support systems (DDS) for FAW control at farm-level in Malawi.	• Systematic review of existing models and fill input data gaps through targeted surveillance. • . Develop phenology of target pests and crops. • Develop an ecological niche and other models. • Modelling pest and disease populations growth and dynamics. • Develop a system for decision-making. • Validate and finetune system outputs.	• Number of reviewed models. • Data gaps identified. • New datasets collected. • Number of phenology models for pests/diseases/weeds. • Number of phenology models for crops. • Number of ecological niche models. • Number of population growth and dynamics models. • Number of finetuned and more accurate DSS.	• Models. • Reports. • Publications. • Source codes.	• Project reports. • *icipe* and partner reports. • Journals.	• Available data for models. • Data policies in place. • Continued funding.
Specific objective: Use of *Cotesia typhae* in the biocontrol of the Mediterranean corn borer in France.					
1. To conduct research and development for assessing the feasibility of a future use in France of *Cotesia typhae* as a new biocontrol agent against the maize stemborer *Sesamia nonagrioides* (Lepidoptera: Noctuidae), an important pest of maize in France.	• To analyze the reproductive success of *C. typhae* and analyze the molecular mechanisms of virulence. This implies a better understanding of the inter-genome interactions that exist between parasitoid wasps and their lepidopteran hosts in general. For that the activities consist: (i) to characterize the bracoviruses of parasitoid wasps (virus types which serve them to efficiently parasitize and develop into the lepidopteran hosts) by genome sequencing of the Cotesia genus available at *icipe*: *Cotesia typhae*, *Cotesia sesamiae*, *Cotesia icipe* and *Cotesia flavipes*; and (ii) to characterize their pattern of virulence by high throughput illumina sequencing of the related caterpillar hosts, respectively: *Sesamia nonagrioides*, *Busseola fusca/Sesamia calamistis*, *Spodoptera frugiperda* and *Chilo partellus*. • To evaluate the potential environmental risk of introducing *C. typhae* in France: risk to non-target insects, risk of establishment and dispersal capacity. • To evaluate the parasitism potential of *C. typhae* against the Mediterranean corn borer on corn plantations in insect-proof greenhouses.	• Good parasitoid production for a biological control program of *Sesamia nonagrioides*, an important maize pest in France.	• Molecular Data. • Biological data.	• Laboratory experiments. • Molecular analyses. • Bioinformatics. • Use of published data.	• Available funding. • Insects available. • Permits from both Kenya and France.

	• To evaluate the feasibility of parasitoid mass rearing with the perspective of industrial production and commercialization.				
Broad objective 2: Make available IPM options for horticultural crops.					
Specific objective: Scale out integrated pre- and postharvest pest management approaches for thrips and tospoviruses infesting vegetables and grain legume crops in East Africa in collaboration with international and national partners by 2023.					
1. Dissemination and scaling of thrips IPM strategies based on intercropping, use of biopesticides and semio-chemicals in Eastern Africa.	• IPM strategies for thrips and tospoviruses widely disseminated and adopted by grain legume and vegetable growers.	• At least 1,000 French bean, tomato, onion and grain legume farmers and stakeholders reached with thrips and tospovirus IPM strategies by 2021. • At least 3 field demonstration of thrips IPM strategies based on intercropping, use of biopesticides and semio-chemicals undertaken in Kenya by 2021. • At least 2 popular articles on thrips and tospovirus IPM published by 2021. • At least 2 publications on thrips and tospovirus IPM by 2022.	• *icipe* reports. • Field demonstration reports. • Media outlets, and radio and TV programs.	• Training workshop minutes. • Field days. • Mass media publications. • Peer-reviewed publications. • Secondary data collection.	• Conducive weather and political conditions permit field activities. • Sustained cooperation between partner organization, NARS, extension networks.
Specific objective: To explore the potentially synergistic relationship between MAT and SIT when applied simultaneously to improve the efficacy of *Bactrocera dorsalis* fruit fly management.					
1. To assess alternative semio-chemicals for treating sterilized *B. dorsalis* before release to minimize attraction to methyl eugenol.	• Pre-release alternative semio-chemicals elucidated for sexual enhancement of sterilized *B. dorsalis* to complement SIT.	• Potential alternative semio-chemicals for sexual enhancement of sterilized *B. dorsalis* screened by 2021. • Potential alternative semio-chemicals for sexual enhancement of sterilized *B. dorsalis* field validated by 2022.	• Project reports. • Publication.	• Laboratory bioassays. • Field trial.	• Partner collaboration in providing sterilized insects. • No extreme weather conditions. • Political stability.
Specific objective: Diversity of endosymbionts and entomopathogens of Dipteran pests and their impacts on dipteran mass-rearing for SIT applications.					
1. Assess the diversity of endosymbionts and entomopathogens in mass-reared colonies of fruit flies, *Ceratitis* sp, *Bactrocera* sp. and the tsetse fly *Glossina* sp.	• Screen mass-reared colonies of fruit flies (*Ceratitis quilicii*, *Bactrocera latifrons*, B. *dorsalis*) and *Glossina fuscipes fuscipes* for endosymbionts. • Screen for entomopathogenic fungi isolates that are less virulent to tsetse fly for compatibility with SIT programs for this pest.	• Diversity of endosymbionts in mass-reared colonies of *B. latifrons*, *B. dorsalis* and *Glossina* sp. documented by 2023. • Alternative fungi isolates that are less virulent to tsetse fly for compatibility with SIT programs identified by 2023.	• Project reports. • Publication.	• Laboratory bioassays.	• Favorable weather conditions. • Partners cooperate.
Specific objective: Upscaling and institutionalizing fruit fly IPM technology among smallholder fruit growers in East Africa.					
1. Establish the baseline damage caused by different fruit fly	• Regular and systematic fruit sampling of mango in the new target locations to ascertain	• Quantification of damage and composition of fruit flies.	• Baseline reports. • Data on fruit damage.	• Baseline survey. • Questionnaire.	• Favourable weather conditions.

species on mangoes and intensify dissemination of fruit fly IPM approaches in the new project action sites in Kenya, Ethiopia and Tanzania.	the damage, abundance and fruit fly composition. • Catalogue and establish the host range of major fruit-infesting fruit flies in the locations and establish seasonality of major mango-infesting fruit flies in the target locations. • Catalogue and assess the level of parasitism by native natural enemies attacking major fruit fly species in various locations in Zanzibar. • Identify suitable and easily accessible sites in consultation with NARS, growers and farming communities in the new project benchmark sites and establish IPM learning sites. • Participatory demonstration activities carried out that encompass various IPM management options and assess the impact jointly with NARS and growers. • Boost colonies of the two parasitoid species (*Fopius arisanus* and *Diachasmimorpha longicaudata*) at *icipe* for introduction and mass releases in the project benchmark sites.	• Knowledge on host range of the main fruit flies. • Knowledge on seasonality of major fruit flies in target locations. • Availability of inventory of native enemies of fruit flies attacking key fruits and their parasitism levels in the project benchmark sites of Zanzibar. • Number of IPM technology sites established. • Number of model farms with display panels. • Number of demonstration sessions on the available fruit fly IPM technologies to growers with NARS. • Number of impact assessments undertaken by NARS. • Condition of *icipe* cultures of the two parasitoid species. • Number of mass releases carried out. • Availability of parasitism levels of the two parasitoid species.	• Project workplan. • Field reports. • Publications.	• Inventories of major fruit flies' host range. • Inventories of pests. • Inventory of natural enemies.	• Security situation does not prevent or interrupt activities. • NARS partners cooperate. • Growers cooperate and allow access to and sampling from their orchards.
2. Develop capacity on IPM and good agricultural practices (GAP) for NARS and growers to support upscaling of fruit fly IPM technologies in the project target countries.	• ToT workshop on fruit fly biocontrol and IPM technologies conducted for extension officers and community extension service providers in the project benchmark sites. • Awareness campaigns and sensitization on availability of fruit fly IPM in project benchmark sites in Kenya, Ethiopia and Tanzania conducted for farmers, farmer groups and the community at large. • ToT workshop on parasitoid rearing carried out at *icipe* for NARS partners on natural enemy production, releases and assessment of impact.	• Number of NARS and community extension service providers (CESPs) trained. • Number of training materials handed out. • Number of awareness campaigns. • Number of growers reached. • Number of NARs trained on parasitoid rearing.	• Training reports. • Photos of on-farm demonstration session in all project countries. • Demonstration sites with display panels.	• Established learning sites. • Model farmer contacts. • Lists of model farmers. • Lists of trainers trained. • Testimonies from trained personnel. • Training certificates.	• Favourable weather conditions. • Security situation does not prevent or interrupt activities. • NARS partners cooperate. • Potential members of CESPs are identified and cooperate. • Local authorities cooperate and participate. • Growers and NARS cooperate.
3. To create linkages and partnerships for enhanced transfer and upscaling of fruit fly IPM technologies and strengthening of	• Approval by county governments to open outlets to supply fruit fly IPM technologies at the grassroot level for growers' accessibility.	• Numbers of stakeholder meetings taken place. • Number of approvals by county governments.	• Meeting minutes. • Meeting and project reports.	• Meeting attendance lists. • Published database. • Stakeholder testimonies.	• Favourable weather conditions. • All stakeholders willing to cooperate.

the mango value chain in Kenya, Ethiopia and Tanzania.	• Database of mango growers in the project countries created. • Linkages between suppliers and growers/growers' association created to increase demand/supply of the fruit fly IPM technologies at the grassroot level and enhance scaling up and uptake of the technologies. • Innovative market information exchange apps (interactive platforms) for fruit fly IPM technologies developed that link the growers (vegetables and fruits) and the suppliers. • Contract and engage NARS partners and growers in resource mobilization at local and regional levels to enable them undertake field testing and continued sharing of the fruit fly IPM technologies in the communities.	• Number of databases of mango growers reached from previous project phases and the proposed phase. • Accessibility of database. • Awareness of private sector. • Number of private sector partners supplying the technologies to the growers. • Number of interactive platforms. • Number of committees formed. • Number of meetings with NARS on resource mobilization for IPM technologies sustainability.	• Written conversation with county governments. • Written conversation with private sector partners. • Project report. • Testimonies from recipients.	• Functional interactive platform of growers and private sector partners. • Meeting reports. • List of NARS and farmer groups. • List of resource mobilization committee members.	• Political stability. • Producers have access to phones and internet. • Suppliers are interested in using the platform. • Local authorities cooperate and participate. • Growers, NARS and CESPs cooperate.
Specific objective: Integrating pest and pollinators management (IPPM) to enhance productivity of avocado and cucurbits among smallholder growers in East Africa.					
1. Avocado-cucurbit- production systems in diverse agro-ecologies characterized for the role of pollinators and insect pests, and associated extrinsic and intrinsic factors.	• Avocado-cucurbit production systems in diverse agro-ecologies assessed.	• Landscape dynamics for cucurbit-avocado production systems in 3 diverse agro-ecology characterized. • Species composition and genetic diversity of insect pests and pollinators and their abundance on target crops in 3 production systems assessed. • Pollination deficit in the target crops assessed in at least 3 landscapes. • Symbionts in key pests and pollinators of cucurbits and avocado characterized.	• Research data. • Landscape maps and GIS databases. • Project reports. • Student theses. • Research publications.	• Satellite imagery. • Ground truth data. • Field survey. • Laboratory bioassays.	• Relevant data made available from different sources. • No extreme weather conditions. (e.g. drought, floods). • Political stability.
2. Potential for integrating pollination and IPM services assessed at landscape level.	• Knowledge of integrating pollination and IPM of the target pests enhanced.	• Pest management practices and floral biology in the target crops characterized by 2019. • At least 4 existing (biopesticide, protein food bait, male attractants, sanitation) and 1 new IPM option for sustainable management of insect pests of cucurbits and avocado adapted for IPPM and implemented.	• Research data. • Project reports. • Student theses. • Research publications.	• Laboratory bioassays. • Field trials.	• Minimal disruptions from biophysical and environmental catastrophes. • Socio-cultural environment in target areas conducive for uptake and adoption of IPM technologies and beekeeping.

		• The nature and magnitude of interactions between the pollinators and IPM practices documented. • Impact of integrating pollination and IPM on key cucurbit and avocado pests and pollinators' health established.			
3. Management interventions for target crops based on improved pollination services and IPM practices adapted, validated and implemented.	• Increased production of quality avocado and cucurbit as a result of enhanced pollination and application of IPM of the target pest. • Income of avocado and cucurbit farmers enhanced.	• Pollination services intensified through their conservation (managed and wild). • Sustainable pollination and best-bet IPM options for cucurbits and avocado promoted. • Impact of enhanced pollination services and IPM on avocado-cucurbit system productivity established.	• NARS and partners reports. • Research data. • Project Reports. • Student theses. • Research publications. • Partnership agreements for technology dissemination.	• Avocado and cucurbit farmer interviews.	• Minimal disruptions from biophysical and environmental catastrophes. • Socio-cultural environment in target areas conducive for uptake and adoption of IPM technologies and beekeeping.
4. Impacts of integrating pollination and IPM services on farmers' livelihoods determined.	• Benefit and impact of integrating pollination services and IPM of the target pest on farmers' livelihoods documented.	• Knowledge, attitude and practices (KAP) towards IPPM documented. • Impacts of IPPM interventions on livelihoods of cucurbits and avocado producers documented. • Ex-ante adoption of IPM pollination services documented.	• Baseline report. • Impact assessment report. • Economic analysis report. • Research publications.	• Avocado and cucurbit farmer interviews.	• Willingness of end-users to participate and respond to questionnaires and provide accurate data.
5. Strengthen capacity, transfer technology and create policy awareness on IPM-pollination integration.	• Knowledge and skills of avocado and cucurbit farmers, growers, extension officers, policy makers and other stakeholders related to IPM-pollination integration enhanced. • A cohort of trained young scientists created.	• At least 3 ToTs and 4 farmer field days on integration of IPM and pollination services targeting 6,100 beneficiaries held. • At least 2 public-private partnership agreements formed to enhance availability of IPPM products for end-users. • At least 3 awareness events targeting growers and policy makers held. • At least 3 PhD and 2 MSc students trained on bee symbionts, integration of IPM with pollination services and GIS/earth observation tools.	• Record of workshops and farmer field days. • Attendance lists of trained personnel. • Training curricula/manuals. • Training reports. • Research publications. • Media reports. • Farmer/extension information materials. • Student theses.	• Training workshops. • Model farmer contacts. • Awareness campaigns. • List of graduate students.	• Mutual willingness of stakeholders to contribute to the successful implementation of project activities. • Expressed need for training.
Specific objective: Combating arthropod pest for better health, food and resilience to climate change (CAP-Africa).					

1. The influence of climate change on pollinators in Kenya and Tanzania documented.	• Past and present pollinators population level and pollination deficit in Kenya and Tanzania determined.	• Historical data collected on key pollinators, pests and natural enemies of avocado, cucurbits, and tomatoes at the action sites by 2022. • Catalogue of pollinator diversities of one of the target crops developed by 2022.	• Project progress reports. • Publications.	• Field survey. • Secondary data.	• No extreme weather conditions. • Partner collaboration in providing historical data. • Political stability.
2. Strategies to mitigate the threat by invasive species in Africa developed and the most critical pathways of entry determined.	• Risk maps and pest risk analysis (PRA) as early warning tools to safeguard against invasion by alien invasive pests documented.	• Number of growers trained on the IPM of key invasive pests of the target crops by 2021. • Ecological models simulated to produce maps for potential threatening invasive species by 2022. • PRA for at least 3 invasive pests threatening Africa documented by 2022.	• Project progress reports. • Publications.	• Testimony of growers trained. • Training reports. • PRA documents.	• No extreme weather conditions. • Partner collaboration in providing historical data. • Political stability.
Specific objective: Assessment of innovative pest biocontrol technologies for sustainable intensification of fruit production systems.					
1. Existing farmers' knowledge, perception and practices that may enhance or constraint the adoption of innovative fruit fly management strategies understood.	• Farmers' knowledge, perception, and practices that may enhance or constraint the adoption of innovative fruit fly management strategies documented and shared with stakeholders.	• 1 baseline survey in at least 2 sites in Kenya and Senegal by end of 2019. • At least 1 working paper by mid-2020.	• Primary survey at household level; qualitative information from key informants.	• Household survey. • Key informants' interviews.	• Farmers will cooperate in providing data.
2. Demonstrate the agronomical and socio-economical effectiveness of innovative fruit fly management strategies on a pilot territory.	• Socio-economic impacts of the innovative fruit fly management strategy established and shared with partners.	• Field pilot experiment (RCT format) in at least 2 sites in Kenya and Senegal by end of 2021. • At least 1 peer-reviewed manuscript by end of 2021.	• Primary survey at household level; qualitative information from key informants.	• Household survey. • Key informants' interviews.	• Other team partners will be successful in developing the IPM interventions in the laboratory for field piloting.
Specific objective: Combating the invasive tomato leafminer *T. absoluta* through the Implementation of an eco-friendly IPM approach on tomato in East Africa.					
1. Classical biocontrol of *T. absoluta* in the target country using the parasitoid *Dolichogenidea gelechiidivoris* undertaken.	• The performance of the co-evolved parasitoid tested in the laboratriy. • Parasitoid released in the field and its impact on the target pest assessed.	• The laboratory performance of the parasitoid against *T. absoluta* determined by 2020. • Field release of the parasitoid undertaken, and parasitism level assessed by 2021.	• Reports. • Publications.	• Laboratory bioassays. • Field surveys.	• Vibrant colonies of the pest and the parasitoid. • Cooperation by the tomato growers and extension officers. • Favourable weather conditions.
2. Socio-economic impact of vegetable pest management technologies assessed.	• Farmers' perceptions of the impact and management of *T. absoluta* assessed.	• Stakeholders and partners made aware of the economic burden of *T. absoluta* by 2020.	• Farmers (men and women).	• Households surveys. • Focus group discussions. • Key informants' interviews.	• Political situation is favourable. • Market value chain actors agree to be interviewed.

	• The economic burden of *T. absoluta* in tomato production in the target project sites determined. • Ex-ante demand for IPM technologies for management of *T. absoluta* among tomato growers estimated.	• Farmers' perceptions of management of *T. absoluta* documented by 2021. • Potential demand of the innovative *T. absoluta* management approaches determined and shared with stakeholders by 2021.	• Key informants (village elders, extension officers, etc.).		
Specific objective: Promote sustainable management of *T. absoluta*, an invasive pest of solanaceous vegetables, for food and nutritional security in East Africa.					
1. Efficacy of potent entomopathogenic (EPF) and endophytic fungal isolate(s) for *T. absoluta* suppression validated.	• Screening and validation of EPF- and endophyte-based pesticides. • Development of an attract and kill product based on pheromone lures and EPF-based biopesticides. • Assess the role of fungal endophytes in inducing systemic resistance against *T. absoluta* in tomato.	• The most promising EPFs validated on large scale by 2020. • Parameters for an attract and kill product based on EPFs with lure strategies standardized by end of 2019. • Induction of system resistance by endophytic fungi explored by end of 2020.	• *icipe* and NARS partner annual reports. • Peer-reviewed publications. • Project reports. • Fungi auto-dissemination device/product for the EPF with lure.	• Laboratory assays. • Field trials.	• No crop failure. • No extreme weather conditions. • Political instability hampering field experimentation. • EPF and lures are compatible. • Effective linkages with NARS and private sector partners. • Private sector partners willing to take up the technology.
2. Solanaceous crop IPM targeting *T. absoluta* validated and demonstrated.	• *T. absoluta* IPM strategy encompassing mass trapping, garden sanitation, agronet technology, endophytes and EPF validated under controlled field trials. • Based on efficacy, availability and acceptability by growers of the various IPM options, an IPM package encompassing at least 2 potent management options demonstrated with growers in the 3 target countries. • Utilization of chemo-ecological characteristics of local wild tomato for *T. absoluta* suppression.	• IPM package for *T. absoluta* validated in at least 1 benchmark sites in each of the project countries by end 2020. • Best-bet IPM options for *T. absoluta* suppression implemented by mid 2020. • At least 2 potent management options of the *T. absoluta* IPM package widely disseminated and demonstrated to growers in the 3 project countries by end 2020. • Blends for *T. absoluta* repellency from wild tomato identified and characterized by end 2021 and evaluated for *T. absoluta* suppression in a push-pull arrangement by 2021.	• *icipe* and NARS partners' reports. • Research data. • Growers testimonies. • Socio-economic reports. • Publications. • Student theses. • National agricultural productions statistics.	• Field trials. • Growers sensitization. • Field demonstration of technologies. • Laboratory bioassays.	• No crop failure. • No extreme weather conditions. • Political stability for field experimentation. • NARS partners cooperate. • Growers allow access to their farms. • Private sector willing to take up the technologies. • Growers willing to take up the technologies.

3. Socio-economic impact of vegetable pest management technologies assessed.	• Knowledge, attitudes and practices (KAP) of at least 2,000 farmers in regard to tomato production and IPM technologies assessed. • Tomato production systems in the target sites documented and shared with stakeholders/tomato supply chain actors. • Stakeholders and partners made aware of the economic burden of *T. absoluta*. • Potential demand of the innovative *T. absoluta* management approaches determined and shared with stakeholders. • Tomato market value chain actors informed about the economic feasibility of commercializing fungal-based biopesticides.	• Baseline survey datasets. • At least 1 report on farmers' KAP on tomato production and pest management in Kenya and Uganda by end of 2019. • At least 1 report before end of 2019. • At least 1 report before end of 2020. • At least 1 peer-reviewed paper by mid-2020. • At least 1 report before end of 2020. • At least 1 report before end of 2021.	• Farmers (men and women). • Key informants (village elders, extension officers, etc.).	• Households surveys. • Focus group discussions. • Key informants' interviews.	• Political situation is favourable. • Farmers agree to be interviewed. • Availability of funds.
4. Capacity of NARS for management of *T. absoluta* strengthened.	• ToT workshop for capacity building of NARS, NGOs and private sector partners on *T. absoluta* IPM in the target countries. • Farmer field schools for hands-on training on IPM technologies. • Public awareness to facilitate large-scale adoption of technologies. • Provide advanced level training to national partners.	• At least 30 NARS from each project country trained on the developed IPM package by end of 2020. • At least 1 FFS conducted in each project country by mid 2021. • At least 2 awareness campaigns undertaken in each project country for large scale adoption of the developed IPM technologies for *T. absoluta* management by the end of the project. • At least 2 PhD and 1 MSc students trained on IPM technologies for *T. absoluta* suppression by end of the project.	• Records of workshops and farmer field days. • Attendance lists of trained personnel. • Training reports. • Student theses. • Publications. • Tailored training programs. • Outreach materials. • Running and updated project website.	• Laboratory work. • Field activities. • Questionnaires. • Field surveys and tomato/solanaceous vegetable sampling data.	• Political stability. • No extreme weather conditions. • Security is favourable. • NARS partners and growers cooperate. • Stakeholders willingness and continued participation in trainings. • Effective linkages with universities established.
Specific objective: Alien invasive fruit flies in Southern Africa: implementation of a sustainable IPM program to combat their menaces.					
1. Sustainability of mango production for food and nutrition security through the adaptation, dissemination and upscaling of proven fruit fly IPM technologies enhanced.	• Enhanced mango yields. • Use of synthetic chemical insecticide significantly reduced.	• Mango yield increased by at least 25% by 2022. • Reduction in chemical insecticide use by 50% by 2022. • 40 demonstration and learning sites for scaling up proven IPM technologies established in Zambia, Zimbabwe, Malawi and Mozambique by 2021.	• Field data. • Laboratory data. • Peer-reviewed publications. • *icipe* and project partners' annual reports.	• Fruit fly monitoring data. • Growers' testimonies. • Lists of participating growers. • Socio-economic reports.	• Political stability in the project countries • Partners' willingness to cooperate in testing and dissemination of the technology. • Growers' willingness to adopt the technology. • Research partners' willingness and capacity to

		• At least 1 working paper on landscape level land use and land cover characterization to guide the implementation of the IPM technologies by 2021. • Maps and a working paper elucidating suitable areas for parasitoid establishment to guide their release by 2021.			contribute to research, dissemination and adoption of the fruit fly IPM technologies. • Favourable weather conditions.
2. The role of biocontrol agents (*F. arisanus* and *D. longicaudata*) in suppression of the alien invasive *B. dorsalis* enhanced.	• Institutional and personnel capacity on application of biological enhancement. • Native and invasive fruit flies significantly suppressed. • National laboratories for parasitoid rearing upgraded.	• Mass-rearing of introduced parasitoids by 2021. • Upgrading national laboratories for parasitoid rearing by 2021. • Obtain and renew import permits for the introduction and releases of parasitoids in the target countries throughout the project period. • Introduction and large-scale augmentative releases of *F. arisanus* and *D. longicaudata* by 2022. • Assessment of establishment, colonization and dispersal of released parasitoids, and assessment of their effectiveness on *B. dorsalis* populations by 2022.	• Report. • Publication. • Theses.	• Laboratory assessments. • Country report. • Dossier for parasitoid import permit. • Field trials.	• Stakeholders and policy makers provide a conducive environment for promotion and use of biocontrol agents. • Import permit of biocontrol agents obtained in time. • A conductive environment exists for mass-rearing of parasitoids. • Partners have capacity to effectively rear biological agents. • Insects are amenable for rearing. • Local capacity available to upgrade laboratories and upgrading completed on time. • Local governments' regulatory bodies and partners are proactive to facilitate granting parasitoid import permits in time. • Political stability.
3. Socio-economic and gender impact of the IPM interventions in the mango production and value chain assessed.	• Differential impact of socio-economic status and gender on fruit fly IPM interventions in the mango production and value chain elucidated and documented.	• At least 1 ex-ante study undertaken by 2021. • At least 100 researchers, policymakers, farmers, extension officers and donors are aware and recognize the economic, social, environmental and human health impacts of interventions by 2022.	• Report. • Publication. • Theses.	• Questionnaires. • Household survey. • Focus group discussion.	• Analytical capacity of national partners and their timely engagement in data analysis. • Participating farmers and other actors will cooperate in providing the necessary information through in-person surveys.

		• The socio-economic and gender impact of the IPM interventions in the mango production and value chain assessed by 2022. • Barriers and success factors for promoting and upscaling IPM technologies among women and youth in the mango value chain understood by 2021. • Cost-benefit analysis of the existing management practices and the proposed IPM technologies conducted by 2022.			• Political and security conditions will allow collection of household surveys in all countries. • Data of sufficient quality available on time, gender-disaggregation of key variables possible. • Capacity of national country teams for timely completion of surveys. • Timely availability of survey data and complementary on-farm trial data. • Proactive participation of partners in developing the M&E framework.
4. Human and institutional capacity for research and development for sustainable mango production in the target countries and beyond enhanced.	• Capacity of the beneficiaries in the target countries for sustainable mango production improved. • National and regional networks for implementation of area-wide fruit fly management Initiated and fostered. • Agricultural innovation platforms (AIPs) to enhance stakeholder interaction and capacity for effective information sharing and market linkages strengthened.	• At least 12 ToT workshops carried out by 2022. • At least 10 AIPs established by 2022. • 10,000 school students (disaggregated by gender) receive education on and become aware of IPM fruit fly management by 2022. • 20,000 extension training materials produced by 2022. • 1 million resource-poor farmers and policy makers aware of fruit fly IPM by 2022. • 3 postgraduate students graduated by 2022.	• Training workshops. • Farmer field days. • Student awareness campaigns. • Distribution of extension materials. • Postgraduate student enrollment.	• Reports on human and institutional capacity building. • Number of AIPs established. • Lists of trained personnel. • Number of postgraduate students trained. • Thesis.	• Proactive participation of partners in training. • Willingness for and active participation of partners to create the network. • Schools collaborate to sensitize students on fruit fly IPM.
Specific objective: An integrated approach to mango production to improve smallholders' food security and incomes in Ethiopia.					
1. To develop, implement and scale a holistic approach to mango production, based on IPM, that will increase production and productivity, reduce crop losses, and promote eco-friendly pest management.	• An integrated mango production approach widely practiced, mango production and productivity improved. • Fruit losses abated and growers' income increased, food and nutritional security enhanced. • Ecologically friendly participatory IPM technologies, information, and biocontrol	• Number of IPM tools scaled. • Number of smallholder growers trained. • Number of nursery and orchard management tools, postharvest handling tools.	• Project reports. • Peer-reviewed publications.	• Laboratory colony, mass-rearing and field release records. • Participatory M&E.	• introduction of the biocontrol agent *Aphytis chionaspis* from South Africa into Ethiopia achieved.

	agents for managing key pests of mango advanced. • Capacity of local institutions and partner skills and knowledge transformed.	• A classical biocontrol program against the white mango scale implemented.			
Specific objective: Establishing the status of the alien invasive *Drosophila suzukii* in Kenya and develop measure for its containment and management.					
1. Delimiting survey for *D. suzukii* in major berry-producing areas undertaken.	• The status and extent of spread of the pest determined.	• The status of the pest in Kenya established by 2021. • The extent of spread of the pest documented by 2021.	• Progress reports. • Publications.	• Trapping data. • Fruit sampling data.	• No extreme weather conditions. • Stakeholders collaboration. • Political stability.
2. IPM measure to contain the pest implemented.	• The pest confined to the detection area.	• The spread of the pest to other areas curtailed by 2022.	• Progress reports. • Publications.	• Trapping data. • Fruit sampling data.	• No extreme weather conditions. • Stakeholder collaboration. • Political stability.
Specific objective: Intensified agroecological-based cropping systems to enhance food security, environmental safety and income of smallholder producers traditional African vegetables in East Africa – AGROVEG.					
1. Biological control and agroecological-based systems using parasitoids, predators, biopesticides and resistant varieties of major TAV pests used by farmers.	• Biological control and agroecological-based systems using parasitoids, predators and biopesticides of major TAV pests validated in a participatory approach. • Certified healthy resistant TAV varieties/cultivars against stem weevils and leafwebbers/leafworms introduced, promoted and disseminated for sustainable intensification in Kenya and Tanzania through a participatory approach.	• Number of households who adopt biological and agroecological-based approaches to control pests. • Number of biological control and agroecological-based approaches tested and ready to be implemented with farmers. • Number of certified TAV varieties tested with farmers, promoted and disseminated.	• At least 3,000 households adopt promoted biological and agroecological approaches. • At least 4 biological control and agroecological-based approaches implemented. • At least 3 certified healthy resistant varieties/cultivars are tested with farmers, promoted and disseminated.	• Socio-economic baseline and end line data. • Testimonials from farmers/farmer interviews. • Farm records and reports throughout production cycle. • Project progress reports. • Research publications. • Student theses.	• Biological control and agroecological-based systems are socially, environmentally and economically sustainable. • Biological control and agroecological based approaches exhibit adequate economic and environmental benefits to attract widespread use by the private sector and other stakeholders. • Cooperation from government regulatory authorities and all stakeholders for successful implementation. • Release permits and other licences required in each country are obtained on time to allow timely validation and release. • Favourable weather conditions.

2. Agroecological-based vegetable farming systems enhanced through strengthened enabling environment with improved market linkages and partnerships, and based on socio-economic impact assessment.	• Agroecological-based vegetable value chains information and marketing platforms strengthened.	• Number of value chain actors participating on project adapted existing market and information platforms. • Number of functional agroecological-based vegetable existing platforms adapted.	• At least 1,500 value chain actors are participating on the market and information platform. • At least 1 agroecological-based value chain information and market platform is functional.	• Socio-economic baseline and end line data. • Testimonials from farmers/farmer interviews. • Farm records and reports throughout production cycle. • Project progress reports. • Research publications. • Student theses. • Number of platforms available.	• There is local and national ownership, government leadership and support for multi-stakeholder dialogue and collaboration, including with the private sector. • Cooperation from all stakeholders to participate in the existing platforms adapted.
3. Knowledge of growers and other stakeholders on agroecological-based vegetable farming systems improved through capacity building among smallholder value chain actors.	• Capacity of vegetable farmers and other value chain actors built.	• Number of farmers and other value chain actors correctly applied recommended agroecological farming approaches. • Number of farmers and other value chain actors trained in good agroecological-based practices.	• At least 80%of trained smallholder farmers and other actors are able to correctly apply recommended agroecological farming approaches. • At least 3,000 farmers and other value chain actors trained.	• Socio-economic baseline and end line data. • Testimonials from farmers/farmer interviews. • Farm records and reports throughout production cycle. • Project progress reports. • Research publications. • Lists/database of trained farmers and other value chain actors. • Student theses.	• Vegetable farmers willing to be identified as lead farmers, allowing their farms to be used as demonstration learning sites. • Willingness of farmers to participate in demonstration activities and trainings. • Farmers and other partners are willing and available to participate in training arrangements.
Broad objective 3: Make available IPM options for industrial crops.					
Specific objective: Generate sustainable wealth creation for improved livelihood and poverty alleviation in rural areas, through a green circular economy and sustainable coffee production (SCP) promotion in Africa.					
1. Implementing and achieving a triple certification scheme: fairtrade (FT), organic (ECO) and geographic indication (GI).	• Mount Rwenzori coffee production chain is capacitated and empowered. • An organized structure is created, which is suitably trained and equipped, and meant to remain operational after the termination of the project.	• Training publication (factsheets, guidebooks). • A practical handbook on the triple certification scheme. • GI book of requirements. • Project database created. • 21,000 contracts with farmers for GI, FT and ECO certification.	• Publications. • Interviews with and contacts of local actors.	• Literature and field exploration. • Interview forms. • Certification contracts.	• Difficulties in training. • Difficulties to make contact with beneficiaries.
2. Creating and implementing a dynamic, interactive knowledge platform, supporting project development.	• A platform providing a powerful organizational tool for information exchange, learning, management (monitoring), visibility and advocacy of the triple certification process.	• GI, FT and ECO certification criteria compendium. • Various site maps created (topography, administration, climate, agrosystems, production quality, quality traceability) for	• Use by farmers and extension agents.	• Field survey. • Cooperative participation. • Wireless internet, mobile phones, interface development for the basic	• Difficulties to use the platform.

		project management and commercial interface (relation with buyers).		structure of the information system.	
3. Expertise transferred to and acquired by partners in the domains of IT, quality management and certification program implementation.	• Farmers' coffee income is improved by a minimum of 35% from certification; a price premium is obtained through the general improvement of Mount Rwenzori coffee performance.	• Quality management procedure. • Recruited staff position. • Social and legal prospective study developed.	• Trade and production data.	• IT procedure documents.	• Lack of local expertise in the area of IT.
4. An IPM strategy for Mt Rwenzori coffee production implemented; a climate change impact assessment and adaptation strategy developed; a GIS system-based, descriptive and dynamic representation of certified Mount Rwenzori coffee production; publicity and visibility of the project.	• The 'green' performance of Mount Rwenzori coffee value chains and SCP practices are implemented are enhanced; waste production is reduced and inorganic chemical are banned.	• Compendium on coffee pest and disease control measures in compliance with ECO certification. • IPM and climate change adaptation strategy guidebook. • Pamphlets, factsheets. • SWITCH regional conference compendium. • Policy recommendations. • Platform implementation.	• Use of the platform.	• Field data. • Climate data. • Research and development databased.	• Difficulties to use the platform.
Specific objective: Support the sustainable development strategy of Uganda's green economy by improving the performance of coffee agroforestry production systems to mitigate climate change impact on the national agriculture and forestry sectors.					
1. Coffee Pest and Disease risk management models designed in agroforestry environment context.	• Coffee P&D epidemics better controlled in innovative coffee agroforestry systems in Uganda, hence reduced economic losses in coffee production.	• Number of farmers adopting improved P&D management tools. • Acreage and regions where improved systems are implemented.	• Farm and tree surveys. • Project reports. • Publications.	• Field visits. • Data sheets. • Publications.	• Lack of interest and motivation from farmers to adopt improved coffee agroforestry production systems. • Lack of political support.
2. Options delivered to diversify farms and farm products with tree product to decrease economic dependence on one cash crop and ensure environmental sustainability.	• Increased tree-based production and increased income of coffee farmers. • Increased production of shade coffee. • At least 50,000 producers are involved in developing improved coffee agroforestry practices.	• Fruit production statistics. • Number of farmers adopting/increasing fruit production. • Number of farmers trained for agroforestry practices. • Number of Lead Farmers trained. • Number of technicians trained.	• Farm and tree surveys. • Project reports. • Cooperative registration documents.	• Field visits. • Data sheets. • Coffee and tree nursery activity. • Number of project recruitments • Lead farmers and extension staff trained.	• Lack of interest and motivation from farmers to adopt improved coffee agroforestry production systems. • Lack of political support.
3. A web-based IT platform implemented to ensure information sharing, facilitate project management (M&E, database management) and enhance project visibility to external stakeholders.	• New management and information exchange tool is created.	• Number of coffee producers with access to web-based knowledge platform. • Number of mobile device applications created. • Number of applications installed. • Number of consultations of the platform.	• Project reports.	• Project database. • Project website, including compendium and factsheets.	• Internet and mobile phone network operational.

		• Compendium generated about coffee and fruit production. • Number of Robusta coffee producing cooperative adopting the platform as a management tool.			
Broad objective 4: Develop push-pull systems.					
Specific objective: Improve ecological and economic performance of push-pull technology (PPT) through comprehensive management of striga, stemborers and FAW infestation in collaboration with international and national partners by 2025.					
1. PPT implemented by over 350,000 farm households, and indirectly benefitting over 2 million people in sub-Saharan Africa.	• Food sufficiency and household incomes of 350,000 push-pull farmers increased by at least 50% by 2025 through higher and sustained crop, fodder and milk yields.	• Acreage of farmland under push-pull. • Household income levels attributable to push-pull. • Number of households having food sufficiency. • Number of farmers having improved dairy animals. • Number of push-pull farmers utilising fodder from push-pull in their dairy production. • Number of dissemination channels optimized and employed. • Cereal and fodder yields and milk production levels among target farmers. • Number of partnerships formed. • Number of stakeholders trained.	• Baseline data, maps and reports. • Ex-ante and ex-post impact assessment reports on household food security, nutrition and incomes. • Project reports. • Country and county sub-program. • Reports by development partners • Scientific publications.	• Baseline surveys. • Ex-ante and ex-post surveys. • Project M&E.	• Commitment and cooperation of national institutions, extension networks and participating NGOs, CBOs, farmers and their support groups assured. • Technical expertise is available for developing new technological innovations and a backstopping framework. • Conducive weather conditions. • No further COVID-19 restrictions imposed. • No climate-change driven crop failures. • Conducive government policies. • Stable political climate. • Partners allocate requisite resources; their priorities and policies remain supportive. • Adequate funding continues to be available.
2. Stemborer management approach developed by exploiting early herbivory traits and plant signalling.	• Novel scientific knowledge on early herbivory and plant signalling generated and applied in crop protection by scientists, extension agents and policy makers by 2023.	• Number of 'smart' maize varieties with early herbivory traits identified. • Number of farmers adopting the use of 'smart' maize varieties. • Increase in grain yields.	• Project reports. • Scientific papers. • M&E reports. •	• Field and laboratory data sheets. • Scientific journals. • M&E instruments. • Surveys. •	• Partners remain supportive. • Farmers willing to adopt the cultivars. • Conducive weather conditions.

	• Staple grain yield increased by 30% for >20,000 farmers in sub-Saharan Africa by 2025 through early herbivory alert.	• Number of food-sufficient households as a result of use of 'smart' maize varieties. • Number of peer-reviewed publications on early herbivory and plant signalling. • Number of stakeholders trained on stemborer and FAW control by exploiting inherent plant defence traits.			• No negative effects of COVID-19 on implementation of the project.
3. FAW management approach developed by understanding the mechanisms by which push-pull controls the pest and by incorporating suitable companion plants in the push-pull system by 2025.	• Scientific knowledge generated on tritrophic interactions and innate plant defences, push-pull control mechanisms and suitable companion plants by 2023. • Scientific knowledge included in integrated management of FAW in Africa by scientists, extension agents and policy makers by 2025.	• Number of scientific outputs generated. • Percentage change in FAW infestation in push-pull cereal fields. • Number of farmers adopting the use of push-pull integrated FAW management approaches. • Number of peer-reviewed publications on integrated management of FAW using PPT. • Number of stakeholders trained on FAW control by using the push-pull strategy.	• Project reports. • Scientific publications. • M&E reports.	• Field and laboratory data sheets. • Scientific journals. • M&E instruments. • Field surveys.	• Partners in the integrated management of FAW remain committed and supportive. • Farmers willing to adopt push-pull for integrated management of FAW. • Integrated management of FAW, including push-pull, is mainstreamed in country policy frameworks. • No negative effects of COVID-19 on implementation of the project.
4. An integrated management approach developed and implemented for striga control in maize in sub-Saharan Africa.	• Food sufficiency and livelihoods of at least 350,000 smallholder farmers improved through efficient control of striga resulting in increases in maize yields by at least 50% by 2025.	• Number of farmers practising integrated striga control methods. • Acreage under integrated striga control methods. • Grain yield increases attributable to integrated striga control. • Number of stakeholders trained on integrated striga control. • Number of publications. • Number of partnerships formed. • Number of partners' joint field days conducted.	• Reports and published papers on integrated striga control. • Project reports. • Scientific papers. • M&E reports.	• M&E surveys. • Project reports.	• No overwhelming confounding factors (e.g. unusual weather, political instability) affect interpretation of the results. • Good cooperation and communication between stakeholders. • No negative effects of COVID-19 on implementation of the project.
Specific objective: Intensify push-pull technology (PPT) to improve food security, nutrition and incomes.					
1. The push-pull system intensified by integrating high-value vegetable crops through farmer participatory research.	• A new push-pull system developed for vegetables.	• Number of farm households reached with the concept of cereal-vegetable push-pull systems to control pests	• Reports and published papers on integrated push-pull vegetable cropping systems.	• M&E surveys. • Project reports.	• Farm households understand the new push-pull/vegetable integration

	• At least 3,000 farmers in Western Kenya reached by 2025 with new knowledge on integration of vegetables in push-pull. • Vegetable production and consumption in 3,000 households adopting the technology increased by at least 20% by 2025. • At least 3,000 famers (including women and youth) increase farm incomes by 30% from vegetable sales by 2025.	• Number of farmers' preferred vegetables to be integrated within push-pull system. • Number of household surveys conducted to find farmers' preference on high value vegetables to be integrated within push-pull system. • Number of market surveys conducted in various target areas to identify farmers' preferred vegetables. • Number of farmers' preferred vegetables identified. • Number of farmer participatory surveys conducted to identify major pests of farmers' preferred vegetables and their management options.	• Project reports. • Scientific publications. • M&E reports.		concept and agree to participate in the research. • No new invasive vegetable pests emerge. • No negative effects of COVID-19 on implementation of the project.
2. Push-pull-vegetable integration options designed and tested; impact of cereal push-pull system on vegetable pests and their natural enemies established; and the chemical ecology of vegetable pest-plant-natural enemy interactions elucidated.	• At least 2 agronomic designs for push-pull/vegetable intercropping tested by 2022. • Proven and validated push-pull vegetable agronomic designs adopted by 3,000 farmers by 2025. • At least 1 study conducted on impact of integrated system on vegetable pests and natural enemies. • At least 2 active semio-chemicals, produced by companion plants, evaluated on the behaviour of vegetable pests and their natural enemies by 2022. • At least 2 publications by end of 2024 on impact of the integrated system on vegetable pests and natural enemies, including mechanisms of pest control. • At least 1 economic study undertaken on the newly designed system by 2024.	• Number of on-station and on-farm trials. • Number of farmers and learning sites adopting new push-pull vegetable agronomic designs. • Percentage reduction of pest and disease infestation in push-pull vegetables cropping systems • Number of studies on impact of the integrated system on vegetable pests and their natural enemies. • Number of active semio-chemicals from companion plants evaluated on the behaviour of vegetable pests and natural enemies. • Number of publications on impact of the integrated system on vegetable pests and natural enemies, including mechanisms of pest control. • Number of economic studies undertaken on the newly designed integrated push-pull system.	• Reports and publications on adoption, field performance and economics of push-pull vegetable cropping systems. • Project reports. • Scientific papers. • M&E reports.	• M&E surveys. • Project reports.	• No confounding agro-climatic changes that impact crop pest loads and diseases.

Specific objective: Combat arthropod pests to achieve better health, food and resilience to climate change (CAP-Africa).					
1. A third-generation climate-resilient PPT developed and scaled up under different agro-climatic conditions and farmers' practices in a participatory approach with stakeholders.	• Climate-smart push-pull extended to 1 additional agro-ecology and 1 additional farming system by 2024. • Climate-smart push-pull adopted by about 100,000 farmers by 2025. • At least 2 policy guidelines developed on PPT transfer by 2024. • 2 impact studies conducted covering Eastern Africa by 2025.	• Number of farmers reached and trained on PPT. • Number and quality of policy guidelines developed on technology transfer recommendations for different farming systems and contexts. • Number and quality of studies on facilitators and barriers to adoption of different technology variants. • Number and quality of impact studies conducted.	• Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports.	• Robust scientific output underpins push-pull adaptation, optimization and scale out processes. • Push-pull successfully implemented in all the sites. • Field extension backstopping measures are in place. • No negative effects of COVID-19 on implementation of the project.
Specific objective: Promote biocontrol of FAW in smallholder cropping systems by enhancing crop diversity and ecosystem services.					
1. FAW resistance of farmer-preferred maize, millet and sorghum varieties assessed, including assessment of response to egg laying (early herbivore alert).	• At least 4 farmer-preferred cereal varieties assessed by 2022.	• Number of farmer-preferred cereal varieties assessed.	• Research data. • Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports. • Laboratory bioassays. • Field trials.	• Farmers remain interested in participating in assessment of potential crop varieties. • Farmer-preferred varieties remain stable against pests and diseases. • The most preferred cereal varieties have the right chemistry. • No negative effects of COVID-19 on implementation of the project.
2. Potential trap plants evaluated to develop a new push-pull system that resists FAW attack.	• A novel FAW-resilient push-pull system, which will include control of stemborers and striga weed, developed and adopted by 30,000 farmers by 2023. • FAW-resistant companion crops, which repel the pest and attract pest's natural enemies (egg and larval parasitoids), evaluated and incorporated in a resilient push-pull system by 2024.	• Number of farmers introduced to a novel resilient push-pull system combining efficacy against stemborers, striga weed and FAW. • Number and quality of companion crops evaluated for FAW resistance, egg and larval parasitoids recruitment and early herbivory alert.	• Research data. • Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports.	• Selected companion plants have high attraction and low survival of FAW larvae. • The trap crop does not become a concentrated source of FAW. • No confounding natural disasters upset the tritrophic balance between FAW, natural enemies and the host plants. • No negative effects of COVID-19 on

					implementation of the project.
3. FAW sampled in field locations to determine which natural enemies attack it in Kenya and conduct experiments to assess tritrophic interactions with crops.	• FAW natural enemies identified in sample field locations by 2022. • Tritrophic interactions between FAW natural enemies and host crops assessed by 2023. •	• Number of FAW natural enemies identified. • Number of experiments conducted to assess interactions between FAW natural enemies and host crops.	• Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports.	• No confounding natural disasters upset the tritrophic balance between FAW natural enemies and the host plants. • Minimal disruptions from biophysical and environmental catastrophes.
4. Chemical and electrophysiological analysis of secondary metabolites conducted from biologically active plant samples.	• Biologically active compounds mediating FAW-host plant-natural enemy interactions determined by 2024.	• Number of plant samples analyzed.	• Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports.	• Studied plants exhibit consistent biochemistry. • No newly emergent pests or diseases attack the selected biologically active plants.
5. New management methods, crop varieties and companion plants for FAW control evaluated by farmers.	• A novel resilient push-pull system validated by farmers in terms of control of stemborers, striga weed and FAW by 2024.	• Number of farmers validating a novel resilient push-pull system for the control of stemborers, striga weed and FAW.	• Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports.	• New pest management methods, crop varieties and companion plants are culturally acceptable to farmers, and offer additional economic benefits. • No negative effects of COVID-19 on implementation of the project.
Specific objective: Scale up biocontrol innovations in Africa.					
1. Current knowledge of Push-pull biocontrol practices analyzed and synthesized, including innovations and traditional practices,	• Study conducted to identify how biocontrol interventions have been successfully adopted, and understand the bottlenecks to further adoption by 2022.	• Number of biocontrol innovations and traditional practices analyzed. • Rate of successful adoptions of biocontrol innovations and traditional practices.	• Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports.	• Farmers fully participate in the evaluation of biocontrol innovations and traditional practices. • No negative effects of COVID-19 on implementation of the project.
2. Farmer-farmer networking evaluated and developed using advances in push-pull biocontrol as a test case.	• Study conducted to evaluate how farmer-farmer networking can be facilitated using a prototype mobile phone-based information sharing system by 2023.	• Number of farmer-farmer networking models evaluated and selected with participation of farmers.	• Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports.	• The biocontrol test case remains relevant to farmers' social contexts. • Farmers full participate in the evaluation of how networking can be

					facilitated using a prototype mobile phone-based information sharing system. • No negative effects of COVID-19 on implementation of the project.
Specific objective: UPSCALE – Upscaling the benefits of push-pull technology (PPT) for sustainable agricultural intensification in East Africa					
1. The understanding and applicability of push-pull scaled up from individual fields to farm, landscape, and regional scales.	• The understanding and spatial applicability of push-pull scaled up in at least 4 countries to at least 25,000 farm households in East Africa by 2024.	• Number of farm, landscape and regional-scale determinants of push-pull success identified and exploited. • Number of functional ecological maps generated to predict insect distribution and yield dynamics from the distribution of push-pull chemical and optical factor. • Number of research outputs produced from knowledge synthesis for targeting upscaling under changing climatic conditions.	• Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports.	• The study regions remain politically stable. • No confounding natural disasters upset the ecological models developed. • Production and yield models have sufficient explanatory power for the available sample sizes and paired designs.
2. The use of push-pull expanded for sustainable intensification in crops and systems beyond cereals through targeted implementation and prediction of push-pull effectiveness and resilience under current and future climate conditions.	• Diversified, optimized Push-pull options scaled out as widely as possible in 5 countries by 2024 • PPT expanded from cereal to at least 4 other crops and cultivation systems by 2024, • The factors influencing push-pull success across scales determined by 2023.	• Number of strategies devised to address barriers to push-pull adoption. • Number of dissemination pathways deployed Number and impacts of transdisciplinary push-pull expansion pathways. • Number of identified socioeconomic and policy barriers to push-pull adoption, including gender-based barriers. • . Number of multi-actor communities of practice established. • Quality of socio-ecological spill-over impacts and governance impacts of upscaling across scales.	• Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports.	• The performance of push-pull is maintained across scales from individual fields, to farms and landscapes. • Push-pull adaptations for new crop systems are developed within the project time frame. • Project partners deliver results and stakeholders remain engaged.
Specific objective: Elucidation of the science and effectiveness of local innovations for managing fall armyworm (FAW) (LIMFA).					

1. To determine the effectiveness of selected local materials for the control of FAW under laboratory conditions.	• Laboratory observation to determine effectiveness of local innovations to control FAW.	• Effective plant extracts, detergent and soil assessed on preference, feeding and survival rates assessed.	• Project technical reports. • Peer-reviewed publication.	• Laboratory assessment.	• Farmers are willing to avail land for the experiment. • No negative effects of COVID-19 on implementation of the project.
2. To evaluate effectiveness of different locally available innovations to control FAW under field condition.	• Participatory evaluation of local innovations to control FAW conducted on-farm in two districts.	• Effective plant extracts, detergent and soil assessed on maize infestation by FAW. • Effect of the treatments on maize yield determined.	• Project technical reports. • Peer-reviewed publication.	• Field evaluation.	• Farmers are willing to avail land for the experiment. • No negative effects of COVID-19 on implementation of the project.
Specific objective: Enhance cropping system resilience under climate change towards sustainable maize production in East Africa.					
1. Levels and stability of pest control and yield under climate change in push-pull cropping systems evaluated.	• Analyze how push-pull cropping systems contributes to maize production levels and stability across land-use and climate gradients by 2021.	• Number of analyses on pests control stability using long term data (10 years) on pest control and yield across different landscapes.	• Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports.	• Availability of all datasets on yield from the 280 selected plots. • No negative effects of COVID-19 on implementation of the project.
2. Predator community composition, food-web structure and functional redundancy in push-pull and monocrop systems evaluated.	• Study pest control levels and food-web structure, and explore whether push-pull increases foodweb redundancy and resilience in different land-use and climate contexts by 2022.	• Number of predator diversity and community composition, parasitism rates and biocontrol effectiveness identified in different cropping systems and landscape structure. • Number of quantitative foodwebs built using a novel approach of estimated densities of predators and predator-prey body size ratios.	• Project technical reports. • Peer-reviewed publications. • icipe and partners' annual reports.	• M&E instruments. • Field surveys. • Project reports.	• Availability of different predators in different cropping systems and landscapes. • No negative effects of COVID-19 on implementation of the project.
3. Ecological and economic effectiveness of push-pull systems under future conditions modelled.	• Model for maize yield formation, predicting where in the region push-pull will contribute to closing yield gaps now and in the longer term by 2023.	• Bayesian state-space model combining yearly time-series data developed for sites with and without push-pull to train a model predicting the effectiveness of push-pull under varying conditions.	• Project technical reports. • Peer-reviewed publications. • *icipe* and partners' annual reports. •	• M&E instruments. • Field surveys. • Project report.	• Availability of different components of the data from different farms in different cropping systems and landscapes.
4. **Specific objective: Develop a push-pull system exclusively for vegetables.**					
1. Cruciferous push-pull cropping systems developed at research stations in collaboration with stakeholders.	• Cruciferous push-pull cropping systems developed.	• Number and quality of companion plants evaluated for push and pull functionality in vegetable push-pull cropping system.	• Reports and published papers on vegetable cropping systems.	• Field and laboratory data sheets. • Scientific journals.	• Push and pull plants for key cruciferous vegetable pests exist.

		• Number of partners or research stations engaged in developing crucifers push-pull cropping systems.	• Project reports. • Scientific reports. • M&E reports. • Student theses.	• M&E instruments. • Field surveys.	• Cooperation of vegetable farmers to survey their farm fields. • No extreme weather conditions. (e.g. drought, floods). • Political stability. • Enough resources to undertake activities.
2. Cruciferous push-pull cropping systems validated by smallholder farmers.	• Cruciferous push-pull cropping systems intensified and used by smallholder farmers, NARS, non-governmental organizations and private sector.	• Number of smallholder farmers and farmer organizations/groups engaged in on-farm trials aimed at validating cruciferous push-pull cropping systems.	• Project technical reports. • Peer-reviewed scientific publications. • M&E reports • *icipe* and partners' annual reports.	• Farmers' testimonials. • Field trial sites surveys. • Scientific journals. • M&E instruments.	• Crucifer push-pull cropping system exhibit adequate economic and environmental benefits to attract widespread use by vegetable farmers. • Selected trap plants have high attraction and low survival of key vegetable pests. • The trap crops do not become a concentrated source of key vegetable pests. • The push plant can effectively repel key vegetable pests.
3. Agroecologial-based vegetable value chains information and marketing platforms strengthened.	• Agroecological-based vegetable farming systems enhanced through enabling environment with improved market linkages and partnerships and based on socio-economic impact assessment.	• Number of functional agroecological-based vegetable existing platforms adapted.	• Project technical reports. • Peer-reviewed scientific publications. • *icipe* and partners' annual reports.	• Field surveys. • Scientific journals. • M&E instruments.	• Cooperation from all stakeholders to participate in the existing platforms. • There is local, national and government ownership, leadership and built support for multi-stakeholder dialogue and collaboration including with private sector.
4. Capacity of vegetable farmers and other value chain actors built.	• Knowledge of growers and other stakeholders on agroecological-based vegetable farming systems improved through capacity building among smallholder value chains.	• Number of smallholder farmers and other value chain actors correctly applying recommended agroecological-based farming approaches.	• Project technical reports. • Peer-reviewed scientific publications. • *icipe* and partners' annual reports.	• Socio-economic baseline and endline data. • Testimonials from farmers/farmer interviews • Farm records and reports • Scientific journals.	• Willingness of farmers to participate in demonstration activities and trainings • Vegetable farmers willing to be identified as lead farmers, allowing their farms to be used as

				• M&E instruments.	demonstration learning sites.
Specific objective: A4a: evidence for the feasibility of scaling up agroecology.					
1. Knowledge on effective barriers and success factors for PPT adoption increased and applied; push-pull and seed production plots established and adapted to local contexts; access to quality push-pull seed is improved and local seed production capacity increased.	• Evidence for feasibility of scaling up of an agroecological approach is established.	• At least 80% interviewed beneficiary farmers use *Desmodium* and *Brachiaria* seeds successfully in the push pull system. • Rapid assessment of main barriers and success factors of push pull determined. • At least 150 push-pull seed production demonstration plots established. • At least 2-3 commercial seed companies engaged in collecting *Desmodium* and *Brachiaria* seeds from farmers.	• Project technical reports. • Peer-reviewed scientific publications. • *icipe* and partner annual reports.	• Farmer interviews. • Socio-economic baseline and endline data. • Participatory M&E.	• Farmers will collaborate in data collection. • Political stability in the project area
Broad objective 5: Make available IPM options for invasive and migrant pests.					
Specific objective: Established a decision-oriented tool to predicting insect damage on crops under climate change by 2025.					
1. Experimentally measure yield losses due to insects, and empirically develop crop damage and loss functions.	• Mechanisms that govern maize yield losses due to insects established.	• At least 1 high impact paper published.	• Laboratory data. • Peer-reviewed publications.	• Experiments using phytotron. • Literature search.	• Maize plants adapt and grow normally in the phytotron. • Insect adapt and feed normally on plants in the phytotron.
Specific objective: A proactive development of biopesticide for sustainable management of the desert locust *Schistocerca gregaria* in Africa.					
1. New biopesticides are developed and available for uptake by private companies for sustainable locust management.	• Portfolio of biopesticides identified to expand supply chains for commercial products. • New isolates screened for commercialization. • Efficacy of existing and new biopesticides assessed against locusts and non-target organisms in the field. • Mass production, novel formulations, shelf-life and improved application strategies assessed.	• Number of isolates tested. • Number of isolates commercialized. • At least on application technique developed.	• Registration dossiers. • Field efficacy and registration trials. • Eco- and mammalian toxicity test reports. • Field efficacy permits. • Progress reports. • Patents. • Student theses. • Publications.	• Validation and new formulation. Registration dossiers. • Laboratory and field data. • Field efficacy permits. • Patents. • Registration permits.	• Favourable weather conditions. • Political stability. • Continued funding. • Collaboration with the private sector. • Collaboration with policy and regulatory authorities.
Broad objective 6: Make available IPM options for soil pests and enhance soil health.					
Specific objective: Microbial uptakes for sustainable management of major banana pests and diseases.					
1. Endophytes and biocontrol agents (EBCAs) identified and selected for bio-management of	• Sustainable intensification of *Musa* spp. and enset crops.	• At least 20 EBCAs screened against banana nematodes and the banana weevil.	• Laboratory screening and efficacy experiments.	• Experimental laboratory and screenhouse trials' data.	• Production of EBCAs possible.

banana nematodes and the banana weevil.	• Improved resilience of *Musa* spp. and enset crops towards key pests and diseases.	• At least 6 EBCAs selected and active against banana nematodes and the banana weevil. • Antagonistic effect of EBCAs combinations tested against banana nematodes and the banana weevil.	• Screenhouse trials. • Progress reports. • PhD thesis.		• Tissue culture banana availability. • Field sites availability. • Field work and research not delayed due to COVID-19 restrictions.
2. Improve/sustain yields through introduction of the selected EBCAs in field assays.	• Contribute to reduced economic losses caused by pests and diseases. • Contribute to reduced use of pesticides, minimising risks for human health with low environmental impact.	• EBCAs for field trials selected and active against banana nematodes and the banana weevil.	• Field trials. • Progress reports. • PhD thesis.	• Field trials' data.	• Adoption by farmers. • EBCAs field performance adequate. • Cost of EBCA products low. • Availability of EBCA products. • Continued funding.
Specific objective: Diagnostic tool for the identification and quantification of the potato cyst nematode (PCN).					
1. A user-friendly tool developed for on-farm detection of PCN.	• Contribute to better agronomic practices by detecting key pests early. • Contribute to reduced pesticide use. • Improved potato yields.	• Soil samples collected in at least 2 agro-ecological sites in Kenya to assess presence/absence of PCN. • Identification of species. • PCN diagnostic tool tested under laboratory and field conditions.	• Field surveys. • Laboratory analysis. • Laboratory and field assessment of PCN diagnostic tool.	• Survey data. • Morphological and molecular data on species identification. • Diagnostic tool data.	• Supply of diagnostic tool delayed. • Diagnostic tool unable to detect PCN in field samples. • Budget overspent. • Project delayed. • COVID-19 related delays.
Specific objective: Capacity building in nematology.					
1. Capacity and expertise in soil health for plant health with focus on nematodes established.	• A soil health platform established in the region. (nematology, branded NemAfrica). • Soil health and nematology expertise established at *icipe*.	• Soil health (NemAfrica) laboratory active and enhancing activities.	• Students scholarships • Students completed their BSc, MSc, PhD at regular intervals.	• Peer review publications. • Thesis submitted. • Presentations at national and international phora.	• Sustaining expertise and challenges obtaining sufficient funding.
2. Awareness of nematodes and their impact on soil health created; the impact of nematodes in agricultural production demonstrated and strategies proposed to combat them.	• Increased awareness and understanding of nematodes in soil health for plant health.	• Training events. • Workshops. • Digital information platform.	• Farmer trials. • Surveys from industry, NARS, research.	• Questionnaires. • Farmer field days. • Farmer trials. • Field surveys. • Research data. • Stakeholder events.	• Adoption by farmers. • Willingness of stakeholders. • Reaching policy makers.

ANIMAL HEALTH at *icipe*

a) Overview of activities

Livestock are vital to food security in Africa. Over two-thirds of the population depend on livestock for their everyday survival, and if these are lost, households can slip into chronic poverty traps. Most livestock in Africa are kept in smallholder farms or pastoralists systems where these are the primary driver of nutrition and income. Improvement of livestock health and productivity, therefore, provides a significant opportunity to improve the livelihoods of these resource-poor people and to help them escape the poverty cycle. It is essential to improve livestock productivity to meet the increased demand for livestock products and to enhance the traction power of oxen for improved agricultural productivity.

icipe and partners continue to apply its considerable expertise and experience in developing tools and strategies for integrated livestock vector and disease control to the two major vectors affecting livestock productivity in sub-Saharan Africa (SSA): the tsetse fly, vector of animal and human trypanosomiasis, and ticks which, among other diseases, transmit East Coast fever. The research will also be enhanced on arthropod vectors with zoonotic potential that are responsible for transboundary animal diseases.

Over the years, *icipe* has developed capacity along the full research continuum, from basic/ strategic research to adaptive research and finally to technology development, transferred through strategic partnerships. The Centre has amassed considerable expertise in quantitative vector ecology, behavioural and chemical ecology, biological control and integration of this basic knowledge in developing technologies in a form that farmers can use themselves. Our research and experience in Africa's two most important vectors of animal diseases—tsetse and ticks—have generated technologies which enable farmers to undertake better ecological management of these and help in intensifying and diversifying smallholders' farming systems. Through this, the income and food security of many have been enhanced. The emphasis has been on developing environmentally safe methods that can be applied together in tailor-made, site-specific packages. *icipe*'s Integrated Pest and Vector Management (IPVM) approach, relies on biological control, use of botanicals and anti-tick pasture plants, repellents and behavioural modification. Components of such a package include the Centre's well-known NGU tsetse traps whose efficacy is enhanced by odour baits, biological control and the use of potent repellents. *icipe* also has gained extensive experience in community mobilisation, empowerment and in developing the management and organisational capacity for successful implementation of the required prevention and control techniques. Indigenous knowledge of communities in the management of ticks and other vectors is incorporated in developing appropriate adaptive control strategies for pests and vectors of animal diseases. Capacity building at all levels of society is an integral part of all *icipe* activities.

Climate change is expected to have an enormous impact on the interactions between vectors, pathogens and their animal and human hosts. Vector-borne diseases are particularly sensitive to global warming because temperature changes can alter vector development rates, shift their geographical distribution and transmission dynamics, or modify host susceptibility to infection. Climate change is beginning to change the map of important tropical diseases like malaria, Rift Valley fever, African trypanosomoses, leishmaniasis, bluetongue disease and dengue fever, among others. Livestock and the ecosystems they depend on are also affected by climate change, and important livestock and human diseases are likely to spread to new regions and become more severe. At the same time climate variation in the tropics, and its effects on the frequency of flooding and drought, could modify the dynamics of the transmission of diseases with the emergence of vectors that alter the population immunity and resistance. Harnessing its unique and extensive expertise in animal and human vectors, and pathogens in sub-Saharan

Africa (SSA), *icipe* will investigate climate-sensitive aspects of vector and pathogen biology to predict changes in disease prevalence to improve vector and disease detection and response.

The Horn of Africa experiences recurrent and extreme climatic shocks, and drought that severely affect food security and livelihoods in this region. These climate shocks adversely affect pastoral communities. *icipe* will assist in the mitigation of this increasingly devastating impact through the development of baits and repellents for biting flies, which includes the major vectors of surra in camels. Camel health and productivity is central to the pastoral economy, and any improvement in this area has a significant effect on its resilience to climatic shocks.

The integrated animal health packages developed for enhancing milk production in Kenya in the smallholder sector offer opportunities for the integration of plant health such as mixed farming practices ('push–pull' for increased fodder production) and human health, such as the livestock protective net-fence that reduces malaria-transmitting mosquito populations. Development of such holistic projects is one of *icipe*'s priorities, and in line with the global One Health philosophy. Evidence shows that investing in smallholders is the most effective method of stimulating poverty reduction and growth, and improving the livelihood opportunities of young farmers, especially women.

b) Goal and Broader Objectives

icipe's animal health research aims to improve livestock health and productivity through the development of integrated strategies and tools for livestock vectors' control, thus leading to greater availability of meat and milk, hides and draught power, and thus enhancing food security.

c) Strategic Outlook (2021 to 2025)

Research on vectors of trypanosomosis (both human and animal) and tick-borne diseases will continue. Greater use of genomics and bioinformatics and behavioural and chemical ecology will be prioritised for technology development, optimisation and implementation. The research will be extended to other arthropods of medical and zoonotic importance, including new emerging infectious diseases, to develop technologies for the integrated management of these vectors and the diseases they cause. Neglected zoonotic tropical diseases are under-researched, although they affect millions of people in mainly rural Africa and have dire consequences for the socio-economic conditions of families and countries. Little is known of how and to what extent the ecological and environmental conditions determine the spread of tropical diseases in Africa and the movement of the disease vectors. Training is thus needed on various levels in order to enhance knowledge in this regard. Climate change may increase the range and efficiency of vectors; but, *icipe* is continuing its research and preparation to deal with these consequences. More holistic projects will be developed to catalyse sustainable agriculture with rural development and to ensure that improvements made in livestock and human health will lead to tangible results in terms of improved food security and poverty reduction. Holistic, innovative, site-specific, packages for sustainable animal health management and animal production will be developed and tested at the farmer/community levels in different production systems and agroecological zones. This will achieve greater potential for successful adoption at the community level. Capacity building to create cadres of research, vector control specialists and managers in livestock IPVM, and increasing the skills and management ability of communities to ensure the sustainability of control efforts, will continue to be given high priority.

d) Specific future thrusts:

Tsetse: As one of the few institutes in Africa working on vectors of trypanosomosis, *icipe* will continue to develop and optimise technologies for effective integrated control of tsetse and the diseases they transmit.

The tsetse repellent technology developed by *icipe* is ready to be rolled out to tsetse affected countries in SSA. This is done in collaboration with other regional and continental initiatives, and in partnership with the African Union's Inter-African Bureau for Animal Resources (AU-IBAR), whose mandate is to support and coordinate the utilisation of livestock for human well-being and economic development in all member states of the AU. The repellent technology will be further optimised and validated for upscaling and commercialisation for large-scale uptake. The prototype dispensers developed will be refined through appropriate partnerships with the private sector into commercial products that are non-metallic, cheap, affordable and easy to use by livestock keepers.

The repellent technology, in general, provides good opportunities for **engagement with the private sector** as, through public-private–partnerships, *icipe* can undertake the technical refinement of the dispensers more effectively. Large-scale validation trials will also be done to determine under which herder and agroecological conditions the technology would work best.

Repellents also open up the possibilities of developing integrated tsetse and trypanosomosis control strategies in conjunction with other control strategies. For example, repellents can be used to push flies away from cattle, and traps or targets used to pull and kill the flies. Alternatively, a few animals can be sprayed with insecticide pour-ons to pull and kill.

Repellents may also be useful in developing barriers to stop reinvasion by flies into controlled areas. Since the current repellents have been developed only for savannah tsetse, they need to be evaluated for non-savanna flies that transmit human sleeping sickness. Thus, research needs to be extended to identify and develop potent repellents for the *palpalis* group of flies (riverine tsetse), which are major vectors of human sleeping sickness. Repellents can be used to protect humans from tsetse bites and thus significantly reduce cases of human trypanosomosis.

Since the identified repellent compounds also affect other biting insects, these need to be evaluated in detail as they may have global implications.

Advances in genomics and bioinformatics, together with detailed knowledge of the behaviour of the flies, will be used for optimising existing baits and for development of new innovative technologies and intervention strategies.

Studies on the characterisation of tsetse–trypanosome interactions are providing a better understanding of the disease epidemiology. These valuable data will continue to be used for the development of novel anti-parasite agents for blocking the transmission of trypanosomes in the vector.

As a **FAO-Reference Centre** for tsetse and trypanosomosis, and as one of the few institutes working on tsetse, *icipe* provides advice and technical support to African countries for vector identification, ecology and interventions against African trypanosomoses.

Biting flies and camel health packages: In addition to tsetse, biting flies (tabanids, stable flies, etc.) also mechanically transmit trypanosomosis (non-tsetse transmitted trypanosomosis) to cattle and camels (i.e. surra), considerably affecting their productivity. *icipe* develops integrated technologies for control of biting flies based on exploitable weaknesses of the vectors along the lines of those developed for tsetse. Improving camel health and productivity has a direct impact on the livelihoods of pastoralists in reducing the effects of recurrent climate shocks and drought in the Horn of Africa region and eastern Africa.

Development of holistic animal health packages: Since several diseases can affect the same animal simultaneously, *icipe* recognises the need for developing and testing of holistic animal health packages for sustainable animal health management and animal production. The Centre

is currently developing such packages in collaboration with Food and Agriculture Organization of the United Nations (FAO), to enhance the productivity of dairy cows in Kenya and pig production in Ghana. The intensive zero-grazing units for milk production will be integrated with *icipe*'s push–pull technology, which focuses on controlling the parasitic striga weed, cereal stemborers and improving soil fertility. Further, *icipe* in partnership with an international team of researchers completely mapped the genome of the tsetse fly. This blood-sucking insect transmits African sleeping sickness in humans and nagana in animals. The precise knowledge of the insect's biology and physiology promises to yield powerful genetic tools that could one day eliminate the disease from sub-Saharan Africa. Such holistic packages will not only alleviate poverty but also enhance food security and human health. *icipe* plans to expand and scale-up these initiatives over the coming years. Such projects, when integrated with the plant and human health activities, have the advantage of impacting the global One Health agenda.

Ticks: *icipe* continues to spearhead the development of simple, sustainable technologies for on-farm management of ticks and the diseases they cause. These on- and off-host tick management strategies will be based on the use of biopesticides, botanicals and behavioural manipulation of the cues ticks use to find hosts, mates and preferred feeding sites. Availability of new technologies for tick control will result in a significant reduction in synthetic acaricide use.

Ticks are obligate haematophagous ectoparasites that transmit a wide range of pathogens to humans and animals. *icipe*'*s* research in this area in Kenya has revealed significant presence of agents of ehrlichiosis, anaplasmosis, rickettsiosis and babesiosis, theileriosis and hepatozoonosis among ticks feeding on, and possibly transmitting to domestic animals with undetermined impact on humans in certain areas of the country. The information therein is essential to public health in mitigating tick-borne pathogens and possible disease outbreaks.

Medical vectors of zoonotic importance: *icipe* will develop new tools and strategies for the integrated management of important arthropod vectors that impact not only transboundary trade but also those with great zoonotic potential. Basic knowledge on the biology, behaviour and ecology of vectors responsible for diseases such as bluetongue, lumpy skin disease and Rift Valley fever will be generated to guide the development of appropriate control technologies. Development of diagnostic tools will also be undertaken, together with the production of predictive maps of disease burden for assisting in the identification of hotspots for guiding interventions. These studies also provide essential linkage with *icipe*'s human health focus.

Climate change interaction: In-depth studies on the effect of climate change on the range and efficiency of vectors will be undertaken to improve their detection and response.

Socio-economic and impact studies: The Centre has long recognised that the quest for effective and sustainable vector control technologies will remain futile unless socio-economic, cultural and environmental considerations are adequately addressed. The success of the development and implementation of integrative control technologies rests on sound longitudinal socio-economic and environmental impact studies. These will, therefore, be central to the progress of this work.

Capacity building: To ensure the sustainability of vector control, *icipe* undertakes capacity building at all levels, including service providers, practitioners, technicians, community health workers and managers of control operations. Furthermore, to enable rural communities to adopt, use and sustain intervention control strategies, *icipe* also helps communities in the establishment of organisational, management and financial community structures through providing appropriate training and surveys, and involving communities in developing the effective control methodologies.

Animal Health Results Based Management (RBM) Rolling Framework

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
Objective 1: To develop a sustainable integrated biorational strategy for controlling vectors of animal trypanosomiasis by 2025					
Effective integrated biorational technologies and strategies for controlling vectors of Animal trypanosomiasis (AT) developed and implemented to reduce AT and increase animal production and productivity	• Four technologies developed for controlling tsetse and biting flies developed by 2025 • At least 100,000 smallholder farmers (30% women and youth) impacted by icipe technologies by 2025 • 30-50% reduction in the prevalence of AT in intervened sites by 2025 • 20-30% increase in animal production and productivity in intervened sites by 2025	• Number of technologies and strategies developed • Numbers of smallholder farmers impacted • % reduction in the prevalence of AT in intervened sites • % increment in animal production and productivity	• Publications • Survey records • icipe and partner databases • Student theses • Reports	• Laboratory studies • Field data collection • Private partners • Government records • Farmer interviews	• Political commitments and support exists • Attitudes and willingness by stakeholders to cooperate • Funds remain available
Specific Objective 1: To develop and evaluate effective, low-cost baits and repellent blends for vectors of camel trypanosomosis (surra) by 2025					
1. Baits and repellents developed for protecting camels against vectors of *Surra*	• One olfactory bait developed and evaluated for vectors of *surra* by 2022 • One repellent blend developed and tested for vectors of *surra* by 2023	• Number of repellents available for vectors of *surra*. • Number of attractants available for vectors of *surra*	• Research data • Peer-reviewed publications • Project progress reports • Student theses	• Project reports • Private partners • Laboratory data and records	• Research funds available
Specific Objective 2: To improve traps and targets for tsetse and biting flies by enhancing the visual attractivity of these by 2025					
2. Improved traps/targets for tsetse and biting flies developed and evaluated	• One trap/target developed for tsetse flies by 2022 • One trap/target developed for biting flies by 2023	• Number of traps and targets developed and evaluated for tsetse and biting flies	• Research data • Peer-reviewed publications • Progress reports • Student theses	• Field bioassays	• Research funds available • Public and private partners willing to evaluate and adopt newer vector control technologies
Specific Objective 3: To upscale the integrated use of novel tsetse and biting fly traps, attractants and repellents in partnership with the private sector 2025					

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
1. The integrated use of traps/ target screens, olfactory baits and repellents optimised in *push-pull* strategies to reduce the transmission of AT	• Three complementary technologies developed for the control of tsetse and biting flies by 2024 • One effective integration of traps/target screens with baits or repellents for tsetse and biting flies 2024	• Number of complementary technologies identified with potential for integration for a push-pull strategy • *Push-pull* strategy optimised and evaluated	• *icipe* project reports. • Peer-reviewed publications. • Project progress reports • Student theses	• Field bioassays	• Identified technologies are practical and fit in farmers' conditions and practices. • National and local organisations cooperate in evaluating technologies • The political environment remains conducive for fieldwork.
2. Technology for large-scale production and distribution of vector control tools passed over to the private sector.	• One agreement signed with private partners for R4D of baits, repellents and traps/target screens by 2024 • One private partner producing and distributing vector control technologies by 2024	• Number of agreements signed with private partners • Number of private partners actively producing and distributing technologies	• *icipe* project reports • Peer-reviewed publications • Minutes from private partners • Records of production and sales from private partners	• Project reports. • Field studies	• The private sector partners remain committed to repellent product and market development.
3. Enhanced advocacy for the use of integrated biorational vector control technologies for tsetse and biting flies	• One advocacy event every year between 2021 - 2025 • Five meetings with multilateral bodies in the agricultural with potential for influencing vector control policies by 2025 • Two meetings annually with the local governments in sites where technologies are upscaled until 2025 • One policy draft for vector control with biorational technologies by 2023	• Number of advocacy events • Number of meetings with multilateral agricultural bodies • Meetings with local governments and national agricultural research and extension systems • Number of policy documents for vector control with biorational technologies	• Press releases for events • Minutes from meetings with multilateral bodies • Minutes for meetings with local county governments and NARES officers • Policy documents and records	• Press statements • Interviews of multilateral bodies, local governments and NARES officials • Policy framework documents	• Sustained funding for advocacy • Multilateral development agencies committed to management of vector-borne livestock diseases
Specific Objective 4: To update tsetse and trypanosomiasis risk maps for Kenya and East Africa					

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
1. Algorithms for predictive mapping of tsetse infestation and spatial risk for trypanosomiasis developed	• One effective algorithm for predicting the spatial occurrence of tsetse developed by 2023	• Number of practical algorithms developed and evaluated	• Algorithms • Student thesis • Peer-reviewed publications	• Programming data • Field studies	• Partners remain committed to developing predictive tools for tsetse abundance and distribution
2. Maps developed for tsetse and animal trypanosomiasis in Kenya.	• One map for the occurrence of Glossina pallidipes in Kwale County	• Number of maps for tsetse distribution in different counties of Kenya	• Tsetse distribution maps • Student thesis • Publications	• Reports of public and private project partners • Reiterative Field studies	
Specific Objective 5: To optimise a strategy for reducing the transmission of trypanosomiasis with enhanced trapping of trypanosome-infected tsetse flies by 2025					
1. Impact of infections with trypanosomes on host animal semiochemicals profile investigated	• Changes in host chemical profile due to trypanosome infections of hosts identified by 2022 • Specific semiochemicals induced by trypanosomal infection identified by 2023	• Chemical profiles for livestock infected with trypanosomiasis • Number of novel semiochemicals identified	• Laboratory datasets • Peer-reviewed publication • Chemical libraries • Student theses	• Laboratory and semi-field bioassays	• Sustained funding
2. Behavioural responses of tsetse and biting flies infected with trypanosomes to trypanosome induced host-specific semiochemicals documented	• Behavioural responses of tsetse and biting flies to trypanosome induced semiochemicals determined by 2022 • Semiochemicals that influence the behaviour of tsetse and biting flies identified by 2023	• Dataset for the responses of tsetse and biting flies to trypanosome-induced semiochemicals • Number of attractive trypanosome induced semiochemicals identified	• Laboratory datasets • Peer-reviewed publication • Chemical libraries • Student theses	• Laboratory, semi-field and field bioassays	• Sustained funding

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
3. Toolkit for detecting trypanosomes induced semiochemicals as markers for trypanosome infections developed (diagnostic kit)	• Biomarkers for trypanosomiasis infections in livestock identified by 2023 • Prototype toolkit for trypanosomiasis diagnosis developed by 2024 • Partnerships established for optimising novel diagnostic kits for trypanosomiasis by 2024	• Numbers of biomarkers identified • Availability of prototype toolkit for diagnosis • Number of private partner agreements for the development of diagnostic kits	• Laboratory datasets • Peer-reviewed publication • Chemical libraries • Student theses • Partnership for R&D documents	• Laboratory, semi-field and field bioassays	• Private partners are interested in developing diagnostic tools
4. Bait for infected tsetse and biting flies developed	• One high efficacy bait for tsetse and biting flies infected with trypanosomes by 2023	• Number of baits for infected tsetse and biting flies	• Field datasets • Bait products piloted	• Field bioassays	• Sustained funding
5. Dispensers for deploying semiochemicals for control of tsetse and biting flies developed	• One dispenser for tsetse and biting fly baits developed by 2024	• Number of dispensers developed and evaluated	• Field datasets • Student theses	• Laboratory and Field bioassays	• Sustained funding
Specific objective 5: Explore the potential use of the tsetse endosymbiont bacteria species, *Sodalis glossinidius* in controlling African trypanosomiasis					
1. Prevalence and density of *Sodalis glossinidius* in wild tsetse populations in Kenya determined	• Prevalence of *Sodalis glossinidius* in *Glossina pallidipes* populations from Lambwe Valley, Homabay Counties of Kenya by 2021 • Density of *Sodalis glossinidius* in Glossina pallidipes populations from Shimba Hills, Kwale County 2022	• Number of datasets for the prevalence of Sodalis glossinidius in wild *Glossina pallidipes* • Densities estimates for *Sodalis glossinidius* in wild *Glossina pallidipes*	• Laboratory datasets • Peer-reviewed publications • Student theses	• Laboratory bioassays • Inspections	• Sustained funding

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
2. Effect of *Sodalis glossinidius* on the establishment and development of trypanosomes in tsetse determined	• *Sodalis glossinidius isolated* and cryopreserved by 2022 • Secretomes of *Sodalis glossinidius* (Sodalis soup) isolated, and the effect on trypanosome establishment and development evaluated by 2023	• Number of *Sodalis glossinidius* isolates cryopreserved • Effect of Sodalis soup on trypanosome establishment and development in tsetse flies documented	• Laboratory datasets • Peer-reviewed publications	• Laboratory bioassays	• Sustained funding
3. Research collaborations established to enhance studies with *Sodalis glossinidius*	• One research collaboration for research with tsetse endosymbionts established by 2021 • One training for research with *Sodalis glossinidius* in *icipe* completed by 2023	• Number of research collaborations established • Number of research associates/students trained	• Project reports • Collaborative agreement documents • Lists of trainees • Student theses	• Training curriculum • Inspection • Project Tests	• Research partners remain interested in researching endosymbiont
Objective 2: Novel tools and strategies for biorational ticks management developed, evaluated and implemented by 2025.					
Effective biorational technologies and strategies for controlling ticks on animal and in ranges developed, evaluated and scaled	• Two biorational products/ technologies for tick control developed, evaluated and upscaled	Number of biorational tick control products developed and evaluated	• Publications • Survey records • *icipe* and partner databases • Student theses Reports	• Laboratory studies • Field data collection • Private partners • Government records Farmer interviews	• Political commitments and support exists • Attitudes and willingness by stakeholders to cooperate Funds remain available
Specific objective 1: Novel bioacaricide for topical application developed, evaluated, registered and upscaled to at least 50,000 smallholder farmers by 2025					
1. Bioacaricide based on *Metarhizium anisopliae* evaluated and registered in different eco-epidemiological settings	• Bioacaricide evaluate in two sites in Kenya and Ethiopia by 2022 • Bioacaricide registered in at least one country	• Number of places where the bioacaricide is evaluated • No of countries where bioacaricide is registered	• Project reports. • Scientific publications produced.	• Laboratory bioassays. • Cattle secondary data collection. • Fieldwork.	• Availability of funds. • Stakeholders remain committed
2. Novel ticks product (bioacaricide) market survey completed in Tanzania and Uganda	• Two market surveys completed by 2023	• Number of market surveys completed	• Project reports. • Scientific publications • Market surveys. • Theses.	• Private sector records • Consultancy firm. • Laboratory bioassays. • Cattle secondary data collection. • Fieldwork. • Herders.	• Availability of funds. • Stakeholders demand alternative tick control strategies. • No competitive public/private interventions take place.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
3. Strategy and tool for area-wide tick control with bioacaricides developed and implemented	• One strategy/tool for area-wide application of bioacaricides developed by 2025	• Number of strategies for area-wide application of bioacaricide	• Project reports. • Scientific publications • Theses.	• Project reports. • Field studies	• Availability of funds.
Objective 3: To sensitise and enhance the capacity of smallholder farmers and national agricultural research and extension systems (NARES) to implement area-wide tsetse flies, biting flies and tick control with biorational technologies by 2025					
1. Train National Agriculture Research and Extension officials (NARES)	• At least three stakeholder trainings held.	• Number of trainings held	• Project reports	• Secondary data collection	• Stakeholders remain committed
2. Train smallholder farmers on use of biorational technologies	• At least three awareness creation workshops held for smallholders	• Number of awareness workshops implemented	• Project reports	• Secondary data collection	• Farmers remain interested in alternative technologies
Objective 4: To increase the training and capacity building for the Biology, ecology and management of livestock and zoonotic diseases vectors by 2025					
1. Train postgraduate students from different countries in sub-Saharan Africa	• At least ten postgraduate students trained by 2025	• Number of postgraduate students trained	• Graduate student lists • Capacity building records	• Secondary data collected • Advertisements for fellowships	• Availability of funds • Students committed to completing studies
2. Train interns	• At least 20 interns trained by 2025	• Number of internships provided	• Capacity building records	• Adverts for internships	• Consistent demand for internships

HUMAN HEALTH at *icipe*

a) Overview of activities

Vector-borne diseases (VBDs) are a significant public health problem throughout SSA. Globally, approximately one billion people are at risk of contracting VBDs. Parasitic diseases such as malaria, leishmaniasis, onchocerciasis, tungiasis and schistosomiasis are among the most prevalent in Africa. In addition, some arboviral diseases (such as dengue haemorrhagic fever, yellow fever, West Nile virus, chikungunya and Rift Valley Fever), and bacterial diseases (such as plague and typhus) are among the re-emerging infections that pose a threat across many countries. *icipe* recognises that an increase in productivity cannot occur without a healthy workforce. The Centre's human health research therefore focuses on improving the health of people so that they can be more active in economic development. Although efforts have been made to reduce morbidity and mortality due to these diseases, they continue to increase in intensity and geographic coverage in certain areas because of insufficient action to break the transmission cycle, and partly due to climate change.

During the 1970s, little attention was generally given to vector control. This resulted in a dramatic decrease in the necessary human and financial resources in many countries in Africa. However, a series of significant events over the last decade have underlined the growing interest and commitment to stepping up efforts to control these diseases. In 1998, the Roll Back Malaria Partnership was launched by WHO, UNICEF, UNDP and the World Bank in an effort to provide a coordinated global response to malaria. More recently, funding from Foundations and the US President's Malaria Initiative, initiatives for the control of Neglected Tropical Diseases (NTDs) are indicative of the support and goodwill from donors as well as increasing political will in Africa through more investment in the public health sector. These have paved way for both the research community and implementing bodies alike to make an improvement in Africa's disease burden.

While current methods have reduced the burden of malaria, one child still dies every minute from the disease. New control tools are desperately needed as mosquitoes develop resistance to insecticides and avoid indoor controls such as bednets, while new evidence shows that resistance to the anti-malaria artemisinin has spread to Africa. In a world first, *icipe* researchers found in 2014 that a naturally occurring chemical attracts pregnant malaria-transmitting mosquitoes – a discovery which could boost malaria control efforts. The chemical, cedrol, found in mosquito breeding sites near Africa's Lake Victoria, could be used in traps that would 'attract and kill' the female mosquito, preventing reproduction before she lays hundreds of eggs. Further, *icipe*'s research on endosymbiont-based strategies have demonstrated that a new microbe, *Microsporidium MB* blocks malaria transmission, opening new avenues for fighting this disease that still kills approximately 500 thousand people in Africa. Transmission blocking of arboviral diseases (e.g. dengue) using endosymbionts has already been demonstrated in several counties. There is great interest in using endosymbionts to control vector-borne parasites such as Plasmodium, and the recent discovery of *Microsporidium MB* will be explored further to advance its potential use to block transmission in nature.

Renewed support for an integrated approach to the control of vector-borne diseases will complement other efforts, such as those focusing on vaccines and drug development, as well as existing vector control tools. *icipe* is contributing to an integrated vector management (IVM) approach by developing environmentally-friendly tools and strategies to control vectors in all stages of their life histories. Specific interventions being pursued include the use of botanicals (such as neem), biopesticides like *Bacillus thuringiensis israelensis* (*Bti)*, biological control through the use of larvivorous fish and attractants identified from preferred plant, human and animal hosts. Furthermore, *icipe* proactively engages communities through downstream research in recognition of the vital role that their participation can play towards breaking the cycle of disease transmission.

a.) Goal and Broader Objectives

icipe's R4D activities in human health contribute to the reduction of vector-borne diseases by developing tools and strategies that control the vectors and break the cycle of transmission, and which can be integrated with other disease management efforts. The broader objectives are to: (i) contribute to the national disease control programmes in several African countries, by focusing on the ecology and behaviour of arthropod vectors; (ii) strengthen linkages and networks with national research and teaching institutions in Africa; (iii) develop IVM strategies for use in different ecological settings; and (iv) contribute to the WHO/AFRO initiative of strengthening vector control capability for the national disease control programmes in Africa.

b.) Strategic Outlook (2021 to 2025)

icipe has established a unit to advance research data management and archiving, in order to enhance utilization. This will help to advance capacity for monitoring and evaluation (M&E) which is an integral part of the vector control strategy. Advanced capacity to evaluate interventions and promote utilization of the science base is needed for promoting the uptake of promising technologies and approaches. This is critical due to lack of capacity and structural framework for institutionalising M&E in vector control programmes in Africa. *icipe* intends to take a lead role in strengthening the co-ordination of a collaborative network of institutions and programmes across the continent to capture available data from key sources and to guide control decisions. Networks and capacity will be strengthened in national disease control programmes at different levels for data collection and management, monitoring vector populations, infectivity and insecticide resistance management. Focus will be given to factors that drive seasonal variability in disease endemicity in different ecological settings in Africa, and geographic parameters that can change, such as introduction of large dam projects. Even though most of the tropical areas of Africa are influenced by the length of the dry season, virtually nothing has been recorded on the influence of the dry season on malaria vector population dynamics in relation to transmission intensity.

Development of new and improved vector control tools*:* Vector control across Africa has been compromised by reduced efficacy of existing tools partly due to emergence of insecticide resistance and lack of functional institutional framework and capacity for the implementation of existing ones. A search for, and the development of, new tools for sustainable integrated vector control programmes in SSA, remains a high priority for *icipe*. One area of interest emanating from studies undertaken to date by *icipe's* R&D is the observation that adult mosquitoes have specific plant feeding preferences. Incorporating biological control agents and insect growth regulators (IGRs) with the mosquito-preferred plants as bait or delivery target is a novel method for vector control. Human odours are still the most potent attractants to mosquitoes. Building on the ongoing development of synthetic odour blends that mimic human attraction, the Centre will continue to optimise attractive blends as well as repellents that can be deployed singly for use in traps or in mosquito push–pull systems.

Investigate symbiont-based strategies to block vector-borne disease transmission: One of the most promising new vector management strategies involves symbiotic microbes that decrease the vectorial capacity of their hosts. In the very recent past, demonstration that a microbe, *Microsporidium MB* completely stops transmission of *Plasmodium* through mosquitoes, demonstrates that these could be an important part of the strategy. Over the last decade, it has become apparent that most insect species harbour vertically transmitted endosymbiotic bacteria and viruses. Studies have shown that these microbes confer their insect hosts with protection against diverse pathogens and are, therefore, attractive tools for the control of vector-borne diseases. By virtue of their vertical transmission (mother-to-offspring) endosymbionts present a more sustainable strategy for the control of vector-borne disease transmission than conventional methods. Research at *icipe* will determine the utility of *Microsporidium MB*, and other symbiotic microbes for controlling vector-borne disease in the African context.

Capacity building within the existing study sites, expansion of activities in other regions and continuing education of African vector control specialists*:* The current decreased efficacy of control measures can, to some extent, be attributed to technical and operational issues related to acute shortage of personnel with sufficient skills and time to provide decisions on vector control at the programme implementation level. Although past capacity building efforts across Africa had aimed at producing skilled personnel for control programmes, only a small proportion plays an active role in vector control. It is on this basis that *icipe* has a focus, through its IVM programme, of training skilled personnel tailored to institutional needs of their respective national disease control programmes. The training aims to enhance skills and knowledge in control and prevention of vectors, and improve the utilising of such knowledge, resources and tools to sound decision making to prioritise disease prevention and control strategies. Capacity building for implementation of IVM policies at the national and local levels will be a core programme area of the Centre's human health R&D. The main purpose of IVM is to improve the efficacy, cost-effectiveness, ecological soundness and sustainability of vector control to reduce vector-borne diseases through the prevention or interruption of disease transmission. Key elements of IVM include integrated approaches, collaboration within the health sector and with other sectors, evidence-based decision-making, advocacy and social mobilisation, and capacity building at the community, researcher and policy-making levels. The Centre will also continue to expand training in disease vector management programmes across Africa in conjunction with participating institutions worldwide.

Establish vector-borne disease early warning systems: Epidemics (of malaria, leishmaniasis, arboviruses and other neglected tropical diseases) occur periodically in many parts of Africa as a result of a complex system of biological, environmental and climate anomalies. These result partly from environmental degradation and the challenge of global warming. It is estimated that at least 110 million Africans live in regions prone to epidemics, and many more are potentially at risk. Because of low levels of immunity among these populations, the risk of death is high in all age groups when epidemics occur. Improved early warning and detection of disease epidemics remain among the key technical elements of the national disease control programmes. *icipe,* working with its strategic partners, aims to improve access to information on climate and environmental variability that could help affected national emergence mitigation and response planning, and their response to disease epidemics more effectively. This will primarily be aimed at understanding the transmission dynamics of vector-borne diseases, predicting the potential impacts of climate change, and the development of early warning systems for disease epidemics. It will also enable the development of decision analysis tools designed to assist policy makers and programme managers with the selection and implementation of vector control interventions, based on prospective scientific assessment of their health, and economic and environmental impacts. The modelling work will build on two decision-analysis support models currently being developed in collaboration with the Millennium Institute, Duke University and the University of Pretoria.

New initiatives on interactions between agriculture and malaria*:* Initiatives in agriculture and health are often pursued in a parallel and in an unconnected fashion. Yet coherent, joint action in agriculture and health could have large potential benefits and substantially reduce risks for the poor. There is growing recognition in political and development sectors that agriculture influences health and vice versa, thus there is need to take advantage of these linkages to improve food security and health. *icipe* will facilitate new initiatives to foster greater interactions between agricultural and malaria control activities in Africa, with the goal of building sustainable partnerships for improved agricultural production and health. An 'eco-health' approach to management of vector-borne diseases will be adopted.

Bioinformatics of pathogens and disease vectors: Capacity in genomics and bioinformatics will be increased for greater integration of these disciplines into the R&D and capacity building programmes. For instance, work on genomics will enable identification of novel target sites for

biorational development of attractants and repellents, and species-specific biocides. To increase our knowledge of genetic determinants of disease occurrence and risk, the Centre will develop research and training competencies in data science, to complement the computational infrastructure, and availability of large and diverse datasets through building capacity in bioinformatics and data science.

Expand human health activities to include emerging and re-emerging infectious diseases: Arthropod vectors, such as mosquitoes, tsetse, ticks and sandflies, are responsible for the natural transmission of most parasitic, viral and bacterial pathogens to humans. The threat of these pathogens as potential emerging infections is real, mainly because of their epidemic potential and the favourable conditions for their transmission that exist in Africa. Good examples are Rift Valley and dengue fevers. Global demographic, climate and societal changes, and modern transportation have provided the mechanisms for these pathogens to break out of their natural ecological zones and become established in new geographic locations where competent arthropod vectors and a large population of non-immune hosts provide permissive conditions for them to cause major epidemics. There are huge gaps in knowledge on the natural history of arthropod-borne diseases in Africa and the relationship between their zoonotic cycles and the ecosystem. *icipe* will continue to expand this relatively new area of its research portfolio. The first major study the Centre intends to make in this area will be focused on the genetic diversity within vector populations and the relationship with landscape ecology to guide the development of appropriate management methods for specific vector populations and the landscape. Other target research areas will include systematics, visual- and olfactory-based trapping systems and combinations, thereof, derived from a better understanding of the role played by different hosts in the feeding and reproductive behaviour of vectors.

Elucidate the epidemiology, transmission and diagnosis of human African trypanosomiasis (HAT): African trypanosomosis has affected settlement and economic development in much of the African continent. Based on data from research conducted todate, capacities exist to increase *icipe*'s R&D activities in the areas of HAT. One of these is to identify trypanosome-specific protein–protein interactions within functionally relevant protein complexes, and use them as targets of anti-parasitic drug screening protocols. *icipe* will also undertake gene expression studies as a basis for designing a sensitive and specific diagnostic test. Diagnosis in Africa depends primarily on microscopic examination of wet blood films, a methodology that is limited both in sensitivity and in ease of use. Further research will be undertaken to develop attractive bait/repellent technologies for the management of riverine tsetse (such as *Glossina fuscipes fuscipes, G. palpalis* and *G. tachinoides*), vectors of human sleeping sickness for integrated disease and vector control. Tools for genetic structuring of the *palpalis* group populations for enabling control activities will be developed.

Conduct research leading to better understanding of the epidemiology and control of leishmaniasis in Africa*:* Visceral leishmaniasis is often under-estimated, while mortality can reach as high as 90% if untreated. *icipe* will lead a network of collaborators in conducting research leading to a better understanding of risk factors associated with transmission of the disease, as well as undertake studies on the biology of the vectors and their control. The Centre will coordinate an integrated project, bringing together experts from different African institutions and partners in the North. Other initiatives include the development of a system for delivery of conidia of entomopathogenic fungi (EPF) into termite mounds and animal burrows for control of the sandfly vectors. Previous studies at *icipe* showed that injection of conidia of EPF into termite mounds successfully kills termites. Since sandflies inhabit eroded termite mounds and animal burrows, a device similar to the one developed for termite control, could be adapted for sandfly control.

Advances in icipe's malaria research and development work: This is on the following fronts:

A new vertically transmitted species of *Microsporidia* was identified in the primary mosquito vector *Anopheles arabiensis*, at moderate prevalence in geographically dispersed populations in Kenya. *Microsporidia MB* infection is localized to the mosquito's midgut and ovaries and does not appear to be pathogenic since it was not associated with significant reductions in adult host fecundity or survival.

We have shown that *Microsporidia sp* can be transmitted vertically (from mother to offspring) and horizontally (from males to females); therefore, several dissemination strategies could be utilized to spread the newly discovered symbiont among mosquitoes. Results from this study have recently been published (in April 2020) in Nature Communications journal (paper link: https://www.nature.com/articles/s41467-020-16121-y). In the study, the scientists report that the microbe, which they have named *Microsporidia MB*, was found in Anopheles mosquitoes. The study was conducted on mosquitoes in their natural environments, mainly on the shores of Lake Victoria in Kenya. The researchers established that mosquitoes carrying *Microsporidia MB* do not harbour malaria parasites either in nature, or after experimental infection in the laboratory. The research also showed that Microsporidia MB is passed from female mosquitoes to their offspring at high rates, and the microbe does not kill or cause obvious harm to the mosquito host.

Endosymbionts and insect vector competency: With a longer-term horizon in mind *icipe* has a growing portfolio of work on the interactions of pathogens with their insect vectors. This work underpins the development of bio-control strategies and provides us with the potential risk profiles associated with such things as climate change and disease transmission. We have initiated an exciting research area on the interaction between symbiotic micro-organisms and their insect hosts with the aim to understand and potentially exploit this relationship.

Arbovirus research: The *icipe* Martin Luscher Emerging Infectious Diseases (EID) laboratory has developed an assay for differentiating various arboviruses in samples, which will have applications for use in surveillance programs. The technology platform also has the potential to be used to differentiate species of plasmodium, mosquito blood meal vertebrate host identification, mosquito species differentiation and Bovine MHC differentiation.

Rift Valley Fever: *icipe* continues to focus on Rift Valley Fever ecology, epidemiology, surveillance and social aspects with the overall goal of understanding disease occurrence, risk pathways, improving early warning and identifying opportunities for disease prevention and control to minimize impact of outbreaks. Recent highlights in this area include:

a) Demonstration that livestock represents a significant reservoir for the virus between human outbreaks.
b) Tests developed for improved RVF vector sampling tools to target primary vectors of RVF, hence improved vector surveillance tools for monitoring RVF risk are in place. And currently, capacity is being built on the use of the tools among public health and animal health stakeholders and also the community.
c) Knowledge gaps on RVF preventive measures were identified among communities in North Eastern hotspot areas within Kenya. Consultations have been initiated with public/animal health stakeholders, livestock owners and herders to address these gaps and recommendation made to the Ministries of Health and Livestock officials to include information in their public health animal health education routine.

Promoting One-Health*:* In recognition of the growing importance of the One-Health paradigm, deliberate efforts will be made to pool together relevant expertise in addressing research issues. This will include a growing component of geospatial sciences to enable a better understanding of disease epidemiology, and knowledge of environmental predictors of disease outbreaks and occurrence.

***Community engagement and participation**:* Community engagement and participation has played a critical role in successful disease control and elimination efforts in many countries. However, the benefits of this approach for malaria control and elimination are yet to be fully realised. This may be due to a limited understanding of the influences on participation in developing countries, as well as the inadequate investment in infrastructure and resources required to support sustainable community participation. The current global malaria elimination campaign calls for a health system strengthening approach to provide an enabling environment for programmes in developing countries. To realise the benefits of this approach, *icipe* will strive to develop the 'people' component of health systems and understand the multi-level factors that influence their participation. The Centre's ultimate goals for disease control will be to: (a) harmonise efforts at building 'competent communities' and harness their efforts towards controlling several vector-borne diseases simultaneously; (b) engage communities in current elimination efforts; (c) optimise health system effectiveness, and (d) develop a community-driven, inclusive and continuous social licence acquisition platform to allow ethical roll-out and testing of new malaria control technologies.

Linking vector control to development: The health sector in many developing countries lags far behind the agricultural sector. Since the agricultural sector is associated with tangible economic gains, resource-poor communities participate more readily in agricultural production-based initiatives. It is, therefore, easier to encourage poor African communities to take up and benefit from new advances in agricultural rather than the medical field, even for a high impact endemic problem such as malaria control. *icipe* will, therefore, strive to nest vector control activities within developmental contexts that confer appreciable economic gains to individuals and families. For example, linking malaria vector control to agricultural production has been shown to stimulate rural communities to take up an active role in implementing disease prevention measures.

Collaboration with government departments: The strength of *icipe* rests in its ability to generate robust scientific knowledge and evidence, which can be harnessed directly for formulation of vector control policies. If harnessed effectively this will enhance the ability of national governments to formulate policies and legislation that are tailor-made for local problems. The Centre will, through the next five years, strive to enter into co-learning activities with regulators in government health and research departments, focusing on R&D activities that are immediately useful to support national and international development. The interactions should initiate and foster the existence of a regularly updated *icipe*-research outcome policy document that provides evidence-based guidance to governments in Africa on vector control initiatives. This is critical in view of the ever-increasing trends towards globalisation.

***Engaging with the science of disease elimination**:* In a traditional sense, disease control implies a focus on morbidity and mortality reduction. However, the science of elimination calls for interrupting transmission of disease. This requires a reduction in transmission and transmission reservoirs and in the rate at which infections are spread. This shift in paradigm corroborates the Centre's mission to improve the overall health status of peoples of the tropics by developing and extending management tools and strategies for harmful and useful arthropods.

Human Health Results Based Management (RBM) Rolling Framework

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
Objective 1: Contribute towards malaria elimination through the development of effective vector control strategies and public health initiatives by 2025					
Specific objective 1.1 To support countries to implement integrated vector management (IVM) approaches for malaria control and elimination; through demonstration of the effectiveness of diversified, environmentally safe innovative vector control methods, capacity building and policy advocacy by 2022					
• Evaluation of the effectiveness of house screening, bio-larviciding and environmental management as additional complementary interventions for IVM in the context of malaria control and elimination. • Improvement of mosquito vector surveillance tools • Cost-effectiveness analyses of IVM approaches involving house screening and/or larviciding relative to exclusive use of insecticide-based methods (long-lasting insecticide-treated nets and indoor residual spraying). • Socio-demographic and socio-economic surveys of households in study districts.	• Research evidence on effectiveness and feasibility of IVM for malaria control and elimination in eastern and southern Africa available. • Reduced burden of malaria in eastern and southern Africa through implementation of IVM strategies and policy efforts. • Reduced health expenditure and lost days of work, school and other activities for individuals and households	• Number of articles on malaria IVM theme published in peer reviewed journals. • At least 3 policy briefs for guidance on implementation of IVM in project countries. • Levels of malaria prevalence and mosquito relative density in study areas with and without IVM interventions. • Change in socio-economic status of households in areas involved in IVM	• Annual project reports. • Social economic impact assessment reports. • Journal publications.	• Review of *icipe*'s projects database • Field visits to IVM implementation sites in eastern and southern Africa.	• National programmes in eastern and southern Africa willing to continue supporting research aimed at generating evidence for guiding malaria control and elimination
• Regular participatory in-country trainings in IVM for malaria control and elimination. • Periodic regional trainings in IVM held at *icipe* in collaboration with multilateral partners including WHO-AFRO and UNEP. • Development of extra curriculum programme on IVM for participation of local schools in malaria control (Ethiopia). • Development of IVM information, education and communication (IEC), and behavioural change communication (BCC) materials.	• Regional and national capacity for implementation of malaria IVM strengthened. • *icipe's* role as a regional hub for IVM training in Africa significantly enhanced from 2020 onwards as a result of increased regional collaboration also involving key partners including WHO-AFRO, UNEP, GEF, Stockholm Convention, and Biovision.	• *icipe's* ongoing role as a co-executing partner and lead research organization for evaluation of new innovative IVM interventions in the context of AFRO-II project Global Environment Facility (GEF)/UNEP- through the main Executing Agency is WHO-AFRO • Number of MSc and PhD students trained in IVM approaches, including in development of vector surveillance tools.	• Project progress reports. • Regional and national training workshop reports. • Journal publications	Interviews with national malaria control programmes (NMCPs). Interviews with WHO-AFRO project staff. Focus group discussions with communities and other stakeholders	• National programmes willing to embrace IVM in view of challenges currently facing traditional insecticide-based methods of vector control, including long-lasting nets and indoor residual spraying. • Countries in eastern and southern Africa continue to be interested in achievement of the goal of malaria elimination at the earliest opportunity.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
• IVM Policy advocacy and dialogue workshops	• Enhanced community participation in IVM for malaria control. • Policy guidelines on IVM for control and elimination of malaria in eastern and southern Africa available	• At least 200 national program staff of eastern and southern Africa countries trained in IVM for malaria control by 2025. • Number of IVM workshops held for policy makers and other key stakeholders. • Number of community members (male and female) trained in IVM for malaria control and elimination in at least seven African countries. • Number of regional IVM training courses for malaria control held at *icipe.* • Number of countries (ministries of health) which have adopted IVM policy for malaria control since 2020.			
Specific objective1.2 Development of non-insecticidal monitoring and control tools based on the odour-orientation behaviour of vectors by 2025					
A potent synthetic lure derived from screening three mosquito-preferred plants developed.by 2025	• Scientists' use of synthetic lure in at least one malaria endemic site in Kenya.	• Number of peer-reviewed publications. • Number of proposals. • Graduate student thesis. • Availability of lure.	• Project reports. • Publications. • Field surveys • Lab analyses	• Laboratory notebooks. • Field notebooks. • Department database. • Adult mosquito responses	Availability of funds.
Studying the influence of invasive plants and metabolites on the breeding ecology and infection success of disease vectors to identify potent larvicides and malaria transmission blockers	• Larvicidal assays to plants and synthesized metabolites implemented • Oviposition assays to plants and metabolites implemented and attractants identified • Knowledge on pathogen transmission modulating activity of plants and/or key	• Publications • Theses/students trained • Proposals submitted • Chemicals tested as larvicides and oviposition attractants • Plants/chemicals tested as transmission blockers for *Plasmodium* or arbovirus pathogens	• Lab analyses including, larvicidal, behaviour and infection assays • Publications	• Lab analyses including larvicidal, behaviour and infection assays •	• Availability of funds • Availability of pathogen cultures

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
	metabolites for potential drug development				
Specific objective 1.3 Transmission blocking approaches developed and deployed by 2023					
The development of symbiotic microbes harbored by mosquitoes as potential tools to control malaria transmission investigated.	• Detailed survey of the symbiotic microbes associated with vector mosquitoes. • Experimental investigation into the effects of harbouring symbiotic microbes on mosquito vector biology. • Discovery of several symbionts with Malaria transmission-blocking properties • Investigation the methods that could be used to usefully disseminate discovered microbial symbionts with transmission blocking capacity.	• No. peer-reviewed publications. • Semi-field tests completed	• Field collection of mosquitoes. • Laboratory and semi-field experiments, including membrane feeding assays (MFA) to quantify transmission-blocking.	• Screening material from the field. • Laboratory assays. • Semi-field experiments	• Discovery of suitable symbiotic microbes. • Additional funding.
Specific objective 1.4 Cattle-targeted interventions for integrated control of human and animal disease vectors by 2024					
Novel biorational products developed for the control of arthropod vectors on and around cattle Impact of cattle-targeted integrated control evaluated in a cluster-randomized controlled trial.	• Private sector partners approached for registration and marketing of products (by 2023). • Further funding applied for Phase III testing of intervention (epidemiology trial by 2023)	• Novel concepts perceived and products developed. • Laboratory tests, semi-field and field experiments completed. • Peer-reviewed publications. • PhD student training and thesis. • KEMRI SERU approval • Study site selection • Stakeholder and community engagement • Data collection tools developed. • Community-based resource persons trained.	• Laboratory and field surveys, • Insectaries and cattle • Qualitative and quantitative field surveys	• Experiments at ITOC and in field sites • Entomological trapping • Animal health surveys • Qualitative surveys, interviews, focus group discussions, open space meetings	• Products perform to the expected standard, • Biopesticide (Metarhizium) provided, • Animal research approval • KEMRI-SERU approval • Animal research approval • Community support • Unexpected restriction for field work •

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
		• Community-based entomological monitoring protocol designed and implemented. • Intervention implemented after baseline year. • Qualitative surveys implemented. • PhD student trained and thesis. • Publications. • Donor reports. • International conferences.			
Specific objective 1.5: Bionomic determinants of malaria vectors in the context of residual malaria transmission in selected ecologies of Eastern Africa done by 2025					
Conduct studies on the genetics and bionomic traits including resistance profiles of malaria vectors	• Knowledge on the distribution of sibling species of major malaria vector groups • Relationship between vectorial traits and malaria transmission established	• Publications • Donor and other reports • Thesis • Interns/students trained • Proposals submitted	• Field surveys • Lab analyses • Sequences submitted to published databases	• Mosquito trapping • Screening samples from the field • Lab analyses	• Availability of funds • Access to study sites • Favourable climate and socio-political situation • Cooperation of communities • No health hazard (e.g COVID-19)
Specific objective 1.6 Risk factors that increase and decrease vector production and malaria transmission based on irrigation and land use assessed by 2022					
1. Assessment of the risk factors that increase and decrease vector production based on irrigation and land use	• Improved awareness of the association between irrigation, land use practices, cropping patterns and vector larval habitats by all project stakeholders by end 2020	• SOP developed • Study boundaries and enumeration of households in study sites complete • Training field assistants on ground mapping of study households using GPS • All risk factors identified and mapped • Publications. • Stakeholder information sharing meetings, workshops and focus group discussions. • Conference presentations • Progress reports	• Farms and other fields within study sites • Households	• Remote sensing and GIS to map study sites • Mapping of land use, cropping patterns and diversity, and frequency of aquatic habitats by ground truth teams. • Larval and adult mosquito surveys.	• Access to study sites. • Smooth cooperation of communities and collaborators. • Equipment performance.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
2. Association between irrigation and malaria vector abundance, seasonality and biting patterns and sporozoite infection established over a 3-year period.	• Improved awareness of the association between irrigation and vectors by all project stakeholders by end 2020	• SOP developed • Training field assistants on adult mosquito sampling • Comprehensive dataset on adult malaria vectors, other mosquitoes and changes in species composition, seasonality and biting pattern compiled over 3 years. • Multivariate risk factor analyses implemented annually. • Publications and conference presentations. • Stakeholder information sharing meetings. • Progress reports	• Farms and other fields within study sites • Households	• Adult mosquito sampling from selected households and rearing. • Molecular analysis for mosquito species identification and sporozoite analysis • Trial.	• Access to study sites. • Smooth cooperation of communities and collaborators. • Equipment performance. • Withdrawal of household from study
3. Association between irrigation and socio-economic and behavioral factors and malaria established over a 3-year period.	• Improved awareness of the association between irrigation and socio-economic factors and malaria by all project stakeholders by end 2020	• SOP developed • Ethical approval granted for study. • Comprehensive dataset on adult household data on socio-economic and nutritional status and behavioural factors compiled over 3 years. • Multivariate risk factor analyses implemented annually. • Publications and conference presentations. • Stakeholder information sharing meetings. • Progress reports	• Household and community surveys and interviews • Key stakeholder engagements	• Individual household questionnaire surveys • Focus group discussion and key-informant interviews • Malaria parasite surveys. • Use of mid upper arm circumference for evaluation of nutritional status • Molecular analysis for Plasmodium species identification	• Access to study sites. • Smooth cooperation of communities and collaborators. • Withdrawal of study participants during survey
4. Geospatial variables for malaria propagation on farm and landscape identified.	• Improved awareness of the important geo-spatial variables responsible for malaria propagation on a	• The spatiotemporal dynamics in terms of expansion of irrigated lands, changes and current status of cropping patterns	• Remotely sensed data • Data collected by	• Remote sensing -GIS mapping	• Access to study sites. • Smooth cooperation of communities and collaborators.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
	farm- and landscape-scale by all project stakeholders by end 2020.	(paddy versus upland crops), and land surface dynamics due to irrigation patterns and soil-moisture regime fluxes in various land-use systems assessed. • Landscape and farm-level changes linked to land-feature specific data on vector diversity, density and abundance data and malaria prevalence and incidence for several seasons. • Publications and conference presentations. • Stakeholder information sharing meetings. • Progress reports	ground truth teams	• Hand-held GPS by ground truth teams	• Equipment performance.
Objective 2: Determination of ecology and epidemiology of arboviral diseases in eastern Africa by 2025					
Specific objective 2.1. To determine entomologic risk of arbovirus transmission and /or outbreaks in selected regions of East Africa by 2024					
1 Distribution and Bionomics of adult target mosquito vectors in relation to climatic variables determined	• Risk of transmission and opportunities for control identified	• Community engagement. • Publications • Donor and other reports • Thesis • Interns/students trained	• Field surveys • Lab analyses • Biological samples: mosquitoes	• Mosquito trapping • Identification of specimens by microscopy Laboratory analyses • GPS coordinates of sampling points	• Access to study sites • Security • Cooperation of communities • Availability of funds • Suitable climate and socio-political situation • Health hazard (e.g., COVID-19).
2 Vector genetics of selected species elucidated	• Variation of disease risk established	• Publications • Donor and other reports • Thesis • Interns/students trained	• Lab analyses • Biological samples: mosquitoes • Sequences in published databases (GenBank)	• Lab analyses •	• Availability of funds •
3 Mosquito larval ecology characterised	• Productive sites mapped for inform targeted control	• Publications • Donor and other reports • Thesis	• Field surveys • Lab analyses	• Immature mosquito surveys • Reared mosquitoes	• Access to study sites • Security

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
		• Interns/students trained	• Biological samples: mosquitoes	• Morphologic identification • GPS coordinates of sampling points	• Cooperation of communities • Availability of funds • Suitable climate and socio-political situation • Health hazard (e.g., COVID-19) • Funds availability
Virus infection rates determined	• Geographic risk of disease transmission • Incrimination of arbovirus vectors	• Publications • Donor and other reports • Thesis • Interns/students trained	• Lab analyses • Biological samples: mosquitoes • Sequences in open databases	• Virus isolates • Lab analyses •	• Availability of funds • Health hazard (e.g., COVID-19)
vector competence of selected species for specific viruses determined	• Insights into disease risk and potential areas of adaptation • The researchers identify the competent and refractory vector populations for arbovirus transmission	• Publications • Donor and other reports • Thesis • Interns/students trained	• Field surveys • Lab analyses •	• Lab infection studies • Mosquito rearing. •	• Availability of funds • Health hazard (e.g., COVID-19)
Specific objective 2.2. To determine the distribution and exposure risk of arboviruses to humans and associated domestic and peridomestic vertebrate hosts					
Seroprevalence of selected arboviruses in humans and other hosts selected areas determined	• Evidence of disease occurrence in population to inform policy	• Publications • Donor and other reports. • Stakeholder information sharing meetings • Thesis • Interns/students trained • Proposals	• Field surveys • Biological samples: host materials. • Lab analyses	• Data on villages & households • GPS coordinates of sampling points. • Laboratory analysis.	• Access to study sites • Security • Cooperation of communities • Smooth cooperation of project collaborators • Availability of funds • Health hazard (e.g., COVID-19) •
Risk factors for arbovirus exposure in humans determined	• Inform policy on disease prevention and targets on vulnerable population	• Publications • Donor and other reports. • Stakeholder information sharing meetings • Thesis • Interns/students trained	• Field surveys • Household surveys	• Questionnaire survey • GPS coordinates of sampling locations.	• Access to study sites • Security • Cooperation of communities • Smooth cooperation of project collaborators

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
					• Availability of funds • Health hazard (e.g., COVID-19)
Biobank of samples and associated metadata established	• Well characterised sample repository for retrospective and prospective studies	• Data sheet • Back up files •	• Back up files • Freezer inventory • Freezer storage	• Back up files • Freezer inventory	• Stable power supply for maintaining sample integrity • Working freezer with enough storage capacity
Specific objective 2.3. In depth virus surveillance, characterisation, and discovery done by 2023					
• Virus biology and molecular characterisation determined.	• Generate data to inform development of diagnostics, vaccines and antivirals	• Publications • Donor reports • Thesis • Interns/students trained • Proposals submitted	• Lab analyses • Virus isolates and/or sequences	• Laboratory analysis. • Computer software. • Bioinformatic analyses	• Availability of funds
• Novel viruses characterised	• Highlight of epidemiology and potential public health importance of novel viruses	• Publications • Donor reports • Thesis • Interns/students trained • Sequences submitted to public databases • Proposals submitted	• Lab analyses	• Infection studies in mice • Growth kinetics • Computer software • Bioinformatic analyses	• Availability of funds • Smooth cooperation of project collaborators •
• Molecular detection tools designed for further epidemic investigation	• Improved capacity and timely detection of circulating novel viruses	• Publications • Donor reports • Thesis • Interns/students trained • Target primers/probes • Proposals submitted	Lab and field evaluations Protocol/SOPs	Lab screening of samples	• Smooth cooperation of project collaborators • Availability of funds
• Improved understanding of the population biology of insect-specific viruses and their potential to block arbovirus transmission	• Foundation established to develop arbovirus transmission blocking strategies that exploit insect-specific flaviviruses	• Publications • Donor reports • Thesis • Interns/students trained • Sequences submitted to public databases • Proposals submitted	• Field surveys • Lab analyses • Biological samples: mosquitoes	• Laboratory superinfection experiments	• Availability of funds and continued access to cell culture lines • Smooth cooperation of project collaborators
Specific Objective 2.4: Design predictive models for arboviral disease transmission by 2023					

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
• Framework for modelling transmission dynamics of different arboviruses developed	Improved early warning system for disease occurrence Prediction of impact of outbreaks	• Publications • Donor reports • Thesis • Interns/students trained • Proposal submitted	• Simulation studies • Publications	• Lab and field data on biologic and climatic variables	• Smooth cooperation of project collaborators • Availability of funds
Specific objective. 2.5: To develop trapping tools for conducting vector surveillance to improve surveillance of YF and dengue.					
• Trapping tools based on primate and human-derived attractants for improved surveillance of YF and dengue in sylvatic and domestic settings developed.	• The team identifies suitable odours and tools for attracting and sampling YF and DEN vector populations. • Effective lures optimized and field tested in sylvatic and domestic settings in Kenya • Odor-baits used by scientists for mosquito surveillance in research programs	• Publications • Donor and other reports • Stakeholder information sharing meetings • Students trained/Thesis • Posters/conference presentations • Presence/use of attractants by researchers and national control programmes	Field surveys Lab analysis	• Mosquito sampling and rearing. • Volatile trapping and analysis. • Trial. • Identification of trapped specimens by morphology	• Access to study sites • Security • Smooth cooperation of communities and collaborators. • Equipment performance • Availability of funds
• Semiochemical basis of larval breeding choice elucidated	• Volatile profiles of different breeding sites characterised for development of lures for gravid cohorts • Microbiota from breeding water and emerged adults characterised • Suitable odours for sampling gravid *Aedes* mosquitoes analysed for field testing	• Publications • Donor and other reports • Students trained/Thesis • Posters/conference presentations	• Field surveys • Lab chemical analysis • Mosquito sampling and rearing.	• Field surveys • Volatile trapping and analysis • Mosquito sampling and rearing • Sequences in GenBank	• Access to study sites • Security • Cooperation of communities and collaborators • Equipment performance
Objective. 3. Understanding freshwater pollution and the links to the distribution of Schistosoma host snails in Western Kenya					
Specific objective 3.1. Association between abundance of host snails for human pathogenic trematodes and abundance of macroinvertebrates with pesticide pollution, assessed by 2022					
1. Risk factor analyses implemented. 2. Pollution associated with abundance of snails, antagonistic invertebrates, and cercaria infection.	• Pesticides bioindicator index developed for the effect of pesticide pollution on macroinvertebrates to tropical freshwater habitats by 2025.	• Filed sites identified • Two field campaigns successfully completed, • Dataset compiled for analysis. • Publications. • Donor and other reports.		• Pesticides and macroinvertebrates (including snails and their parasites) will be monitored after run-off events in freshwater	• Access to study sites. • Smooth cooperation of communities and collaborators. • Equipment performance.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
		• Thesis chapter.		habitats in western Kenya • Host snails will be collected and investigated for cercariae.	• No unpredicted climate events.
3. Pesticide sensitivity established in comparison to antagonistic species.	• Tools available to predict impact of pesticide pollution on snail distribution by 2025.	• Toxicity tests designed and successfully implemented. • Publications. • Donor and other reports. • Thesis chapter		• Acute toxicity assays with field-collected organisms	• Access to study sites. • Smooth cooperation of communities and collaborators. • Equipment performance.
Specific objective 3.2. Spatial and longitudinal roisk factors for Schistosomiasis transmission in river systems in western Kenya assessed in association with agricultural and industrial pollution by 2024.					
1. Experimental assessment of impact of pollution on predator-prey relationships, snail vector competence and parasite survival.	• Risk of schistosomiasis based on habitat pollution assessed for predicting disease risk by 2024.	• Macrocosm experiments established and completed, • Database established, • Publications. • Donor and other reports. • Stakeholder information sharing meetings. • Thesis chapter.		• Macrocosm experiments under semi-field conditions	• Equipment performance.
Objective. 4. Investigating the disease ecology of tungiasis (sand flea disease) for the development of treatment and prevention strategies					
Specific objective 4.1. Developing tungiasis prevention tools by 2025					
Impact of novel prevention tools known.	• Recommendations for prevention made to Ministry of Health for incorporation in the Kenya National Guideline for Tungiasis Control by end 2025.	• Proposals developed. • Funding secured. • Ethical approvals from KEMRI granted. • Project staff training completed. • Field tests completed. • Datasets compiled for analysis. • Statistical analyses. • Donor reports. • Publications.	- Field samples - Development and testing of novel floor materials - Testing of neem solution and pyriproxyfen (insect growth regulator) for control of off-host stages of sand fleas.	• Bioassays • Semi-field trails. • Filed tests. • Randomized controlled trials.	• Funding • Access to study sites • Community consent

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
Specific objective 4.2: Identify the factors driving intense transmission & responsible for a high tungiasis disease burden					
• Environmental behavioural socio-economic risk factors identified • Intra-domiciliary and extra-domiciliary transmission sites identified • Seasonal changes in transmission dynamics analysed and described	• Factors driving intense transmission & responsible for a high tungiasis disease burden identified. • County and National MoH and NTD Unit engaged and recommendations provided by 2022.	• Ethical approval from KEMRI-SERU granted. • Study locations selected. • Stakeholders identified and engaged. • Cross-sectional studies in schools and household (HH) in three endemic areas implemented. • Examination of soil/floor sample, systematically collected during the cross-sectioned and the longitudinal studies, analysed. • Molecular tools for identification of off-host stages developed and applied. • Longitudinal studies (school, HH, floor, soil during dry and wet seasons implemented. • 2 manuscripts • PhD student training • Donor reports and presentations	• School and community surveys	• Qualitative surveys in schools and households	• SERU approval • Approval of County Administration • Consent of community and assent of children • Unforeseen interruption of field work
Specific objective 4.3 Understand pathogenesis & identify determinants of severe morbidity in tungiasis by 2023					
• Impact of tungiasis on life quality documented • Impact of tungiasis on academic achievement documented • Novel rapid assessment of tungiasis-associated inflammation established • Scores for acute and chronic pathology validated • Impact of T. penetrans on host mobility documented • Pathogenic bacteria in inflamed lesions identified and pig as model for tungiasis associated	• Impact of tungiasis on cognitive child development estimated. • Care giver behaviour risk factors established. • Guidelines for thermography for pathology survey compiled. • County and National MoH and NTD Unit engaged and recommendations provided by 2023.	• Development and application of tools to assess tungiasis-associated life quality impairment in children • Development and application of tungiasis-associated impairment of school performance • High resolution infrared thermography for quantifying inflammation surveys implemented • Semi-quantitative assessment of clinical pathology completed, • Impaired mobility [using pedometers and GPS-trackers assessed.	• Field surveys in schools and households, • Animal samples • Molecular analysis	• Qualitative surveys and assessments • Molecular laboratory assessments	• Approval of County Administration • Consent of community and assent of children • Unforeseen interruption of field work

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
morbidity in humans validated.		• Small scale metagenomics analyses comparing bacterial infection of tungiasis lesions between human and pigs implemented.			
Specific objective 4.4 Determine the ecology of off-host stages of *T. penetrans* by 2024					
• Optimal transmission conditions identified • Seasonality in development of off-host stages described • Environmental conditions for off-host stages identified	• Better understanding of the heterogeneous distribution of tungiasis in different climate and ecological zones. • Contribution to prediction of disease outbreaks by end 2024.	• Soil/floor sample surveys implemented. • Identification of off-host stages completed. • Repeated cross-sectional studies (school/HH/floor) during dry and wet seasons completed. • Field experiments to assess environmental conditions needed for off-host development done.	• Soil surveys in schools, households and in laboratory	• Field collections	• SERU approval • Approval of County Administration • Consent of community and assent of children • Unforeseen interruption of field work.
Objective 5: Understanding leishmaniasis transmission dynamics in Kenya and development of control strategies by 2025					
Specific objective 5.1: Risk mapping and bioecological studies of leishmaniasis disease vectors					
Determination of densities, species diversity and host feeding preference of sand flies	New vectors of leishmania species identified in Marsabit and Gilgil Vector species of leishmaniasis from various habitats in disease endemics regions documented Sandfly densities recorded Source of bloodmeals established	• Publication • Project reports • Conference presentations.	• Sand fly habitats • Study villages • Villages & households.	• Vector sampling • Sample analyses • Coordinates recording • Laboratory analyses	• Distance to the study sites. • Access to the homesteads • Security. • Harsh climatic conditions
Leishmaniasis parasite identification	• Vectors screened of leishmaniasis parasite species	• Publication • Project reports • Conference presentations.	• Field samples	• Vector trapping • Laboratory analysis.	• Access to the homesteads • Security. • Harsh climatic conditions
Elucidate the plant feeding ecology and habitat preference of sand flies	• Extent of plant feeding among different sand fly species determined • Specific plants fed upon by sand flies identified	• Conference presentations • Peer-reviewed publications • No. of graduate students/thesis produced	• Field surveys • Volatile trapping from different substrates • Morphological analysis in the lab	• Vector trapping • Lab analyses	• Approval of County Administration • Cooperation of the community • Favourable climate and socio-political situation

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
	• Plant derived attractive volatile organic compounds identified • Sand fly composition and diversity in selected habitat types determined • Semiochemical basis for habitat selection in sand flies assessed	• Data on preferred sand fly host plants • Plant-derived attractants identified • Funding	• Chemical analysis in the lab • Lab bioassays		
Investigate pheromone and host-derived communication in sand flies	• Pheromones produced by the CL vector *Phlebotomus duboscqi* identified • Behavioural response in lab and field to candidate compound(s) assessed • Sand fly response to enantiomers of 1-octen-3-ol determined	• Protocol for chemical analysis established • Conference presentations • Peer-reviewed publications • No. of graduate students/thesis produced • Funding	• Lab analyses including bioassays • Field surveys	• Lab analyses • Vector trapping	• Approval of County Administration • Cooperation of the community • Favourable climate and socio-political situation
Specific objective 5.2: To develop an odour-baited sandfly attraction trapping device - the "SanTrap" for the control of leishmaniasis					
Development of odour baited sandfly attraction trapping device - the "SanTrap" for the control of leishmaniasis	• Novel approach in the control of sandfly bites developed • Efficacy and efficiency of the attract-and-kill tool on sandflies established	• Publications. • Reports • SanTrap tool • Patent	• Study villages • Attractant prototype •	• Vector sampling. • Sample identification. • Laboratory analysis	• Access to households • Trap testing villages • Household consent
Specific objective 5.3: Epidemiological factors associated with cutaneous leishmaniasis transmission in Gilgil, Nakuru County, Kenya.					
Vector species for Cutaneous leishmaniasis and parasite transmission in Gilgil, Nakuru County identification	• Identification and mapping of cutaneous leishmaniasis vectors • Ecological factors mapping • Cutaneous Leishmania reservoir identification	• Publications. • 1 MSc • Stakeholder information sharing meetings.	• Study villages • Habitat types • Ecological parameters	• Vector sampling. • Sample identification. • Laboratory analysis	• Trapping sites access
Correlation of exposure to sand fly bites and the CL outcome and the risk factors associated with disease exposure in Gilgil	• Identification of exposure to sand fly bites and the associated risk factors	• Publications.	• Study villages • Patient screening • Habitat types	• Vector sampling • Patient samples analyses Laboratory analysis	• Access to study sites. • Patient consent

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
Specific objective 5.4: Identifying sand-fly endosymbionts and their potential effect on *Leishmania* transmission.					
Diversity of *Wolbachia*, *Rickettsia*, *Spiroplasma*, *Arsenophonus*, *Ochrabactrum Serratia, Cardinium*, and microsporidia symbionts in Kenyan sand-fly species done.	• Identification and mapping of endosymbionts	• Publication • Stakeholder information sharing meetings.	• Field collection	• Vector sampling. • Sample identification. • Laboratory analysis	• Trapping sites access
Experimental correlation of symbiont infection with infectivity to *Leishmania*	• Establishment of sand-fly colonies • Identification of transmission blocking potential of key endosymbionts	• Publication	• Experimental data • Established sand-fly colonies	• Clearing of symbionts in subset of colonized sand-flies • Experimental infection of *Leishmania* parasites in sand-flies with and without symbionts	• Maintaining stable colony of sand-flies

ENVIRONMENT HEALTH at *icipe*

1. Overview of Activities

a. Bee Research

Previous research has been focused on sampling and estimating the presence of threats to honeybees and stingless bees acting as important managed pollinators. We have used our established networks to sample pest, pathogens and also test for pesticide residue levels in bee colonies spread over the African continent. We were able to establish the first records of the ectoparasitic mite *Varroa destructor* for Kenya (in 2009) and Cameroon (in 2017). Furthermore, we have established that pseudoscorpions are present, which have a well-known role as predators of *Varroa*. We have recently extended our *Varroa* research and were able to show that African bees show an increased hygienic behaviour towards the mite and that increased grooming activity coupled with higher damage reduces *Varroa* levels in African bees. Varroa is not the reason for absconding of African bees, and this behaviour is rather due to shortage in pollen and reduced levels of brood. In 2017 the African Reference Laboratory for Bee Health was accredited as an OIE Collaborative Centre for Bee Health in Africa. As OIE Collaborative Centre we have contributed to training and sensitizing Countries national wildlife focal points in Africa and the Middle East on the importance of wild bee pollinators and their role for biodiversity conservation and food security, both for anglophone and francophone countries.

Virtually all insects harbour beneficial microbial symbionts that have a profound effect on insect biology. Honeybees harbour a simple and specialized gut microbiota that has been shown to be involved in many physiological processes of the host such as digestion, detoxification, and immune responses, amongst others. *icipe* started bee symbionts research in 2017. During this time, we have characterized for the first time the African honeybee gut microbiota as well as the gut microbiota of eight species of Stingless bees. This work has set up the basis for future studies addressing the potential use of the gut microbiota as probiotics for bee health as well as research in host-microbe co-evolution involving different bee sub-species.

Bees, like any other animal, require essential nutrients, however, the key nutritional requirements for honeybees and plant sources that produce the optimal supply of these nutrients remains largely unknown. The efficiency of use and preference of the available food source may vary with bee species, age, sex and caste. Plants (pollen, propolis, nectar and resin) are the main food sources for honeybees, though some bees are known to feed on honey dew and other exudates. Poor nutrition, attributed to loss of their natural habitat, climate change and increase in monoculture crops, has been associated with declines in honeybee colonies since bees are no longer able to obtain the necessary variety in their diets and have consequently become more susceptible to the effects of pesticides and diseases. So far, research has shown that nutritional content from different plant species and regions varies widely yielding various nutritive values for bees. Furthermore, the availability, quality and diversity of plant species translate into the nutrients available to the colony and reflect the health status of the bees. Together, *icipe* believes that a better understanding of these factors will increase the potential and role of honeybees in agricultural production, biodiversity conservation and plant health. Recently we showed that diverse pollen diets enhance the survival of worker bees when compared to monofloral diets.

We studied the pollination of various species of stingless bee compared to honeybees in setting fruit and seed yield as well quality on most common greenhouse food crops such as sweet melon, cucumber, bell pepper and water melon. We were able to demonstrate that on cucurbits such as sweet melon and cucumber, stingless bees such as *Hypotrigona gribodoi*, *Meliponula bocandei*, *Meliponula lendliana* and *Plebeina hildebrandti* are more efficient pollinators than *A. m. scutellata* because we found that pollination by this species yielded the largest and heaviest fruits and the highest seed numbers and sugar content. We also demonstrated that fruit quality and seeds quantity in cucurbits such as cucumber increases with the number of visit a stingless bee species accomplished on a flower with quality being higher in flowers pollinated by *M. bocandei.* Better fruit quality of cucumber when

using honey bee as pollinator can only be obtained from multiple visit of a same flower; while in stingless bees, a higher fruit quality and seed quantity are obtained during a single flower visit due to their long probing time on a flower compared to honey bees. We also worked on sampling and understanding the pollinator diversity of Macademia crops in Kenya and estimating their contribution as pollinators to fruit yield and quality of Macadamia. Moreover, the interaction between stingless bees as pollinator and flower nectar sugar composition and their associated micro-organism was also investigated to understand the plant-pollinator interaction between stingless bees and honeybees.

b. Climate Change and Biodiversity

We sampled different groups of insects with special reference to the orders Diptera and Hymenoptera. Amongst them we have a strong focus on pollinators and parasitoids. For some of these groups, extensive revisions of genera or higher-level taxa were conducted. For a few pest insect species, distribution modelling approaches have been successfully applied. We explored a few approaches for climate-smart pest management. We have studied the relationships between climate change (increased temperatures) and crop-pest interactions, e.g. in coffee production systems.

We started to use landscape as a significant ecological factor. We have studied the landscape effects on the productivity of beehives and their infestation with pest insects. Furthermore, we have studied the effect of landscape on the delivery of ecosystem services as pollination and natural pest regulation. We found that diverse landscapes were hosting a large abundance of pollinators, while medium and low landscapes histed much less pollinator insects, however, on the pollination service of avocado plants the landscape level had only marginal influence.

We have adopted the system of using freshwater macro-invertebrates as indicators of water quality. This has been done together with local communities, so that a locally available grading system allows those communities to assess the quality of freshwater systems, which are their only source of water for everyday use.

c. Beneficial and Commercial Insects

From the past two years, the Environmental Health Theme (EHT) had been interested in contributing research on understanding the role of some insects and microorganisms in synthetic, organic, and chemical waste degradation to promote their use in waste recycle. Recently, the EHT made a request to the Government of Kenya through its Ministry of Environment to partner for research and capacity building in waste management by using the potential of insects.

Sericulture is the rearing of silkworms for the production of silk and has a broad agricultural base seen as an effective tool for rural development. There are various entrepreneurial opportunities in this industry starting from mulberry to fabric production. Sericulture is a relatively new venture in Africa, where mulberry and silkworms are mainly exploited only for silk production. *icipe* through 4phase project, contributed to strengthening sericulture in Uganda and Kenya in early 2000. Research and use of wild silkmoths alongside bees in forest conservation was enhanced through Global Environment Facility- United Nations Development Programme (GEF/UNDP) during 2005–2007.

Since 2015, YESH I and ongoing MOYESH project in Ethiopia has established and promoted entrepreneurship and agribusinesses skills that have transformed livelihoods of thousands of unemployed youth by generating decent jobs and income through honey and silk-based products. This project activities indicate that the potential of sericulture in Africa is multifold and is yet to be fully tapped. The main focus of R4D activities planned for 2021 - 2025 strategy is to explore new horizons beyond silk and add value to products within the silk 3Fs (Fabric, Food and Feed). The focus on sericulture will be to develop appropriate technologies for production of silk and non-silk by- products along the silk value chain and support establishment of business enterprise to empower especially youth and women. This will be supported by pertinent research to diversify by-products. Castor oil from the plant seeds can be used for a wide range of cosmetic and medical purposes. Mulberry is used to produce beverages like herbal tea, fruit juices and wine among other products like animal fodder, fertilizers and cosmetics. Pupa from silkworms can be explored for production of animal feed but can

also be used as a source of protein for humans because of its high protein. The research activities will also focus on genetic analyses to improve maintenance programs and future breeds for silkworms.

Additionally, we developed domestication and management methods of various species of stingless bees occurring either only in East, West or Central Africa for livelihood sustainability through honey production or food crop pollination.

d. Applied Bioprospecting

Bioprospecting is a systematic and organized search for useful products derived from bioresources including plants, microorganisms, animals, and others that can be developed further for commercialization and overall benefits of the society. The applied Bioprospecting component of EHT undertakes research and capacity building for livelihood improvement, biodiversity conservation and climate change mitigation in the following areas: a) discovery, development, and commercialization of products from biodiversity for pest, vector, and disease management, b) promotion of sustainable production, commercialization and use of nature-based products through Private-Public-Community Partnerships (PPCP), and c) capacity building of natural resource-dependent rural communities to sustainably produce pesticidal and medicinal plants and products for pest, vector, and disease management.

e. Insects for food, feed and other uses

Cataloguing and conserving edible insects: Over 2,000 species of edible insects have been recorded globally, with over 500 species in Africa. However, little has been done to establish a comprehensive reference collection of these insects. Studies are needed on their biology, ecology and nutritional profile and this knowledge will guide conservation efforts.

Wild harvesting and mass-rearing technologies: Wild harvesting of insects for human consumption is routinely practiced across sub-Saharan Africa. Wild insects are harvested seasonally using rudimentary methods, which are largely costly, hazardous, inefficient and destructive for natural habitats; and may yield insects that are unsafe for human consumption. *icipe* is developing improved, safe and cost-effective technologies for wild-harvesting *Ruspolia differens* and *Rhynchophorus phoenicis*. Moreover, some edible insects, such as termites, locusts and *R. phoenicis* are notorious crop pests. National and regional locust control programmes focus on mass-spraying breeding sites with insecticides, yet they could be harvested as nutritious food or feed. Therefore, improving on the efficiency of trapping these insect pests should have dual benefits of protecting crops and directly contributing to food and nutritional security. Furthermore, *icipe* and its partners are developing and scaling mass-rearing protocols for *R. differens*, *R. phoenicis*, the African mealworm *Patchnoda sinuata*, crickets and the desert locust.

A supportive policy framework and changing attitudes on entomophagy: Mainstreaming insects as food and feed is a relatively new concept, and regulatory policy frameworks on the use of insects for food and feed are largely absent. Negative attitudes are persistent among many societies on using insects as food and feed. *icipe* is engaging relevant authorities in Kenya (Kenya Bureau of Standards), Uganda (Uganda National Bureau of Standards) and other countries to establish safety standards for use of insects as food and feed. Generation of data on nutritional, safety and anti-nutritional properties of edible insects is critical as supporting evidence to advocate for policies that promote consumption and use of insects in feed. Holding promotional campaigns on edible insects will aid in achieving consumer acceptance.

Postharvest handling and value addition of edible insects: Edible insects value chains in Africa are still in their infancy. *icipe* in collaboration with partners are studying different technologies for storage, processing and packaging of edible insects, as well as different recipes for *R. differens*, *R. phoenicis*, crickets, lake flies, termites and the desert locust. Value-added insect products will require suitable agribusiness models and knowledge on consumer acceptance.

Insect-based feed in poultry, fish and pig production: *icipe* has established a strong scientific basis for use of insect-based protein feed in poultry, fish and pig production, and demonstrated technical and economic profitability of black soldier fly inclusion in feed for farmed animals. Based on the increasing demands from the private sector and especially from youth and small-scale farmers, technologies need to be further streamlined on-farm including testing different supply and upscaling pathways as well as developing gender-sensitive business models that are suitable for job creation and income generation. Also, the performance of livestock produced with insect-based feed under on-farm conditions needs to be investigated, and integrated approaches using frass fertilizer and other soil enhancement products from insect farming need to be developed.

2. Goal and Broader Objectives

a. Bee Research

The goal of our integrative bee health research is: *To improve the overall health of honeybees and other important pollinators to ensure optimal delivery of pollination services for increased food and nutritional security*.

*icipe´*s goal is to increase honeybee fitness and thus, increase rural and vulnerable populations income as well as enhancing bee pollination services. This will be achieved by investigating: a) how parasites and pathogens adversely affect bee health, b) how pesticides and other environmental chemicals impair bee health, c) how to exploit beneficial gut microbiota-host interactions, and d) how honeybee nutrition impacts bee health and bee productivity. In this context, we will also explore how other managed bees support agricultural production and human health through pollination. We will understand how landscapes support pollinators biodiversity and impacts on agricultural production and human health through pollination services. We will enhance knowledge and skills of students, scientists, and rural and wider African communities in arthropod diversity and environmental health-related disciplines.

b. Climate Change and Biodiversity

The goal of our integrative climate change and biodiversity research is: *To improve the overall understanding of factors contributing to the distribution and performance of different insects (pests, beneficial insects) in terms of adaptation to their environment and to protect the environment by the use of biologically friendly, agro-ecology driven approaches for reducing the use of conventional pesticides in pest-management.*

Landscape level approaches are important for an optimal set-up of interventions in agri-ecological production for an optimal delivery of ecosystem services. Detecting changes in habitats and the environment, and monitoring systems based on insects as bioindicators can utilize the sensitivity of some insect groups. Local communities can be trained in using these bioindicators for monitoring.

c. Beneficial and Commercial Insects

The goal of the Commercial and Beneficial Insects programme is: *To conduct multidisciplinary research in Apiculture, Sericulture, and Meliponiculture amongst others to create knowledge on the diversity and of functions and products that can be utilized from insects to help alleviate poverty, ensure food security and improve environmental health in Africa.*

d. Applied Bioprospecting

The Applied Bioprospecting programme has the following objectives: *(i) To discover, develop, and pilot technological innovations, products, and applications for pest and disease control and management, pharmaceuticals, and cosmetics along with the dissemination of research results, transfer of technologies, influence of policies, and build capacity of communities, NARES and other stakeholders; and (ii) to engage in sustainable and eco-friendly agricultural production, and income generating*

activities that contribute to the conservation of biodiversity and improve the quality and health of the environment.

3. Strategic Outlook 2021 to 2025

a. Bee Research

We want to move from descriptive sampling studies to hypothesis driven research questions. We aim to a) define how different pests, diseases, and pesticides are affecting African honeybees, b) establish solutions for best management of these risks to improve bee health, and c) investigate if honeybee diseases are transmitted to other bee pollinators such as stingless bees and carpenter bees and understand the mechanism of transmission.

With respect to the gut microbiome research, within the next five years, we plan to continue the deep characterization of the beneficial bacteria that live in the bee gut. While *A. mellifera* harbours a conserved and simple gut microbiota, recent findings have uncovered a large hidden diversity at the strain level, and this, most likely translates, into novel phenotypes and novel potential use of such microbes to enhance bee health. Moreover, it has also been reported that honeybee gut microbiota is shaped by seasons, landscape and host genetic background. A better understanding of all these factors in Africa will allow us to better support the adoption of modern beekeeping practice to improve livelihood. Additionally, African indigenous biodiversity may have answers for the serious challenges of other regions around the world face. Understanding the co-evolution between the honeybee and its gut microbiome, in this natural environment, could provide important tools to mitigate the global bee colony losses.

Concerning other managed pollinators like stingless bees, we have had a first look into the composition of their microbiomes. Preliminary results show that their gut microbiome is very species specific and populated by conserved bacterial phylotypes. Stingless bees do not have the cosmopolitan capabilities of their sister, the honeybees; they are very susceptible to environmental chances and most of the time to not develop when moved from to different locations. A better understanding of the role of such specific gut microbiota will allow us to improve stingless bee domestication and stingless bee derived product production. Together, it will improve stingless bee keeping adoption in rural areas and diversify livelihood of targeted populations.

We plan to start by identifying the nutritional requirements for African honeybee including the daily intake/consumption. An analysis of the daily intake/consumption of honeybee colonies (manage and feral), and its effect on bee physiology (immune system, weight gain, bee productivity, etc.) will be performed. Once beneficial nutrients are identified, nutrient content from various plant species (chemical components of pollen, nectar, resin and propolis) will be identified and their availability addressed in order to have a better picture of the seasonal or regional variability of this nutrients. Additionally, we will evaluate the role and efficiency of the gut microbiota in the digestion of such components. Finally, we will address bee behaviour towards these nutrients and/or nutrient containing plants. Bee plant/flower preferences over the year will be determined and the spatial mapping of such resources will be established. Finally, by experiments conducted in the field, we will determine the link between bee nutrition and colony productivity and determine the visual, olfactory, gustatory cues that bees use to locate specific plants.

We want to understand the interaction between bees and plants to elucidate a) how different agroecological zones are affecting African pollinators diversity and their health (colony development and productivity), b) the pollination efficiency of managed bees on other commercial food crops such as blue berry and strawberry, and c) the foraging and recruitment biology of other managed bees.

b. Climate Change and Biodiversity

We want to move from descriptive sampling studies to hypothesis driven research questions to infer a) how different factors influence the distribution of pest and beneficial insects, and b) how

anthropogenic influences (land use/land cover changes) and climatic changes are affecting the distribution and performance of those insects.

We want to study how agro-ecological intensifications will contribute to a) pest management and b) climate change resilience. Approaches will include the study of the effects of intercropping, mulching, agro-forestry, flower strips, crop rotation, and fallows. We want to understand overall landscape complexity and specific landscape elements and how they influence arthropod performance and hence the delivery of ecosystem services. From these analyses we aim to select significant and easy to implement management strategies and test their effectiveness under different circumstances as changing environments. We will study the assemblages of arthropods in selected environments (eg. freshwater systems, forests) along with carefully selected environmental variables, including changes in the makeup of functional groups over time.

c. Beneficial and Commercial Insects

We will do an assessment on the biodiversity of insects that can be potentially used for recycling of synthetic, organic, and chemical waste in terrestrial ecosystems in East Africa. By identifying these insects, we will have the ability to conceive and experiment friendly mechanisms where they can be used for waste management in human managed terrestrial systems such as urban waste dumping sites. We will also assess the biodiversity and investigate the ability of some water ecosystems insects to degrade organic and chemical waste for uses in water recycling systems such as in aquaculture or aquaponics production in East Africa. Insects can also be bred on organic waste, in high numbers, and on small surfaces, therefore, making large scale industrial breeding possible. If these “bio waste degrading” insects are found, we also plan to evaluate the beneficial microbes that populate their guts since it is very likely that they are implicated in this process. The knowledge will also allow rural communities to assess quality freshwater for home used and cattle beverage mainly in areas with limit access to good water source. Additionally, understanding the interaction between locally efficient terrestrial and aquatic recycling of insects and microorganisms may allow to develop a proper efficient mechanism for their use in waste management and the use of this degraded waste for agriculture.

The programmes will focus on promoting knowledge and technology-based entrepreneurship through capacity building in beekeeping and silk farming. The sericulture component will study and work on improved silkworm strains with desirable characteristics such high cocoon production, pathogen resistance and high-quality silk fibre. This will be backed up by establishing silkworm germplasm management unit for hybrids adaptable to African environment.

We will also focus on understanding how landscape floral composition influences the honey physico-chemical composition and bio-active properties of African stingless bee species compared to the Western honeybee, *Apis mellifera* (Hymenoptera: Apidae: Apini). There is need to satisfy the demand of farmers on stingless bee colonies in order to reduce pressure on wild colonies. Therefore, we will develop *in vitro* methods for mass production of virgin queens and *in vivo* methods for mass production of nuclei colonies. The need of uzz pollinators for efficient pollination of food crops such as tomatoes, egg plants and others will imply the need to develop domestication and management methods of carpenter bees.

d. Applied Bioprospecting

Biopesticides and semi chemicals have attracted attention in pest management in recent decades and have long been promoted as prospective alternatives to synthetic pesticides. Biopesticides have also attracted great interest in the international research community, with a significant increase in the number of publications devoted to the subject. On the other hand, semio-chemicals have been exploited in several ways to manage insect pests. These include monitoring and detection, population suppression through mating disruption, mass trapping and attract-and-kill techniques.

Biopesticides have not yet reached the desired level of use, whereby they could displace the dominance of chemical pesticides, given that the commercialization of new products in the market is lagging. Currently, biopesticides comprise a small share of the total crop protection market globally,

with a value of about $3 billion worldwide, accounting for just 5% of the total crop protection market. Future research on biopesticides and semi chemicals for insect pest management should focus on innovative formulation for field deployment as well as on optimization of controlled-release technologies and trapping efficiency.

4. Specific Future Thrusts

a. Bee Research

We hope to drive our integrative bee health research to another level through integration of different disciplines, new methods, and partnerships. We are looking forward to developing new tools for diagnosis especially applicable to difficult field conditions in Africa and suited for resource-poor farmers. An example for this will be the future development of an antibody-based diagnostics tool for the detection of different bee viruses. Furthermore, we want to start utilizing bees as environmental sentinels for the detection of pesticides and antimicrobial resistance (AMR). While the first can be done via pollen sampling and pesticide residue analysis on specific botanical origin pollen, the second might work via the pick-up of AMR genes through the microbiome. However, we also want to exploit the gut microbiome for the development of probiotics to increase a) bee resistance against natural pathogens, b) bee resistance against pesticides and herbicides, and c) bee resilience against climate change. With a better understanding of the function of the bee gut microbiome role and its evolution we will promote important scientific knowledge about host-microbe interactions and also contribute to enhancing efforts in domestication of (stingless) bees.

b. Climate Change and Biodiversity

Through improved methods for digital data collection and thereby increasing the participation of non-scientists we envisage larger number of samples with spatial and temporal collection information to be processed resulting in higher resolution and real-time data for the African continent. Ecological intensification of agriculture is on the rise, as it is promising for tackling climate change induced risks, enhancing multiple ecosystem services (e.g. pollination, natural pest regulation, soil health and water retention). Agro-ecological approaches have been shown to be successful in the long-term due to their environmental friendliness. Monitoring will be conducted by trained members of local communities as only through specialized insects with narrow ranges of environmental tolerance detailed and small-scaled environmental assessments are possible. Integrating local communities into this work will increase the manpower needed for such projects and, because the local community's relationship with habitats they utilize is very strong, and their motivation for accurately monitoring their environment will produce robust, reliable data.

c. Beneficial and Commercial Insects

Study will be conducted by sampling and identifying associated insects and micro-organism cohabiting in terrestrial and aquatic waste dumping sites. The role of each associated insect and micro-organism in the ecosystem will be understood through existing knowledge. Insects with potential synthetic, organic, and chemical biodegradable activities will be reared and tested in small experimental units. Positive treatments will be retested at larger scale to assess their effectiveness for accurately monitoring to produce robust, reliable data. The programmes will stimulate and facilitate development of sustainable agribusiness value chains for beekeeping, silk farming and high value complementary activities, by empowering communities especially for young men and women with appropriate business and technical skills, through capacity building, knowledge sharing, and creating an enabling business environment.

d. Applied Bioprospecting

We will optimize the current developed products for interventions for malaria control and identify opportunities to integrate efforts with other initiatives in discovery, development, and commercialization of nature-based products for pest, vector, and disease management. A main focus will be on determining the effects on non-target organisms and defining the mode of action of developed products.

Environmental Health Results Based Management (RBM) Rolling Framework

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
Objective 1: Survey, inventory, and description of new species of East African insects published and data made internet-accessible by 2025.					
1.1 At least 50 international experts agree to study and publish results of examination of insects collected in Burundi and Kenya, by 2025.	• Taxonomists agree to study East African specimens.	• Number of taxonomists agreeing to participate.	• Collaborative agreements agreed through emails.	• Copies of agreements made available.	• Taxonomists' priorities change. • Kenyan authorities change their insect export policies.
1.2 At least 25 manuscripts produced by 2025 exclusively devoted to, or incorporating significant numbers of, East African insect taxa.	• Taxonomists study and publish on East African insect taxa.	• Number of manuscripts published on generic revisions, species descriptions, and regional checklists.	• Journals index.	• Online publication searches.	• Risk (small): Collaborators end cooperation with *icipe*.
1.3. At least 100,000 insect specimens databased by 2025, and targeted groups (pollinators and parasitoids) matched, where possible, to unique-specimen barcodes and made available on the internet on the Global Biodiversity Information Facility (GBIF –(http://www.gbif.org)	• Taxonomists and biogeographers access data base.	• Number of visits to GBIF, including number of downloads of database information.	• Global Biodiversity Information Facility (GBIF –(http://www.gbif.org)	Access records from Global Biodiversity Information Facility (GBIF –(http://www.gbif.org)	• Barcodes are available. • Manpower is sufficient.
1.4. At least 10 taxonomists or biogeographers cite (via GBIF) *icipe* collection database in papers or reports by 2025.	• Taxonomists and biogeographers access data base and use data in independent reports or papers.	• Number of reports or published papers.	• Journals index.	• Online publication searches.	• Data is not uploaded in time to influence researchers by output date.
1.5 At least 350 new species discovered in East Africa and described in peer-reviewed journals by 2025.	• Knowledge of East African insect diversity is increased and National Museums of Kenya type collection increased appreciably.	• Published papers with collector and georeferenced location refer to ICIPE-provided type specimens.	• Journals index.	• Online publication searches.	• Enough undescribed species are sampled to enable us to reach our proposed output. • Expert taxonomists continue to express interest in studying insects from East Africa. • Kenyan government continues to allow export of non-endangered insects for study in external institutions.
Objective 2: Information on important pollinating Diptera (true flies) collected and made available on the internet by 2025.					
2.1. ICIPE's collection of fly pollinators databased and made available to	• Data on Diptera important in plant pollination services made available to	• Number of visits to GBIF, including number of downloads of data.	• Global Biodiversity Information Facility (GBIF –	• Access records from Global Biodiversity	• Grantee (Royal Museum for Central Africa) completes the database on

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
the international community on GBIF by 2025.	conservation biologists, taxonomists and interested parties.		(http://www.gbif.org)	Information Facility (GBIF – (http://www.gbif.org)	sub-Saharan fly pollinators including the Kenyan data, low risk.
2.2 Three field visits per year through end of 2025 made to Kenyan forests and savannahs to increase the collection of Kenyan wild-bee pollinators	• Information on wild-bee pollinators is increased, underscoring importance of non-Apis bees in providing pollination services.	• Database of wild-bee pollinators increases during period indicated	• Comparison of numbers of known Kenyan wild-bee pollinators at beginning https://www.discoverlife.org/mp/20q?guide=Apoidea_species&flags=HAS, and end of defined period.	• Access records from online list of Kenyan bees	Funding available for field research (low risk)
Objective 3: Taxonomic information on African insects including major African pests and vectors used by scientists, students and public by 2025.					
3.1 One training session per year on insect identification for ARPPIS students and other interested staff conducted through 2025.	• Students and staff know and apply modern taxonomic techniques, including preparation morphological identification, and DNA techniques to identify insects.	• Number of students and staff members trained	• Counting participants and modules.	• Test analysis	• Students and colleagues have time and interest to participate in the courses
3.2 At least four donor-funded projects with relevant taxonomic perspective request and receive taxonomic and/or photographic support from the Biosystematics Support Unit by 2025.	• Scientists incorporate taxonomic information into planning and carrying out of projects	• Number of projects funded that incorporate taxonomic data.	• Donor and *icipe* internal reports and publications.	• Online publication searches, requests to administration and donors.	• Sufficient calls and project partners available requesting taxonomic support.
3.3 At least two major training events for international postgraduate students in taxonomy and collection management held at icipe by 2025 as part of the NORHED II funded project on taxonomy and insect collection management	• Taxonomy, identification of insects, and collection development assumes new importance in informing project development in sub-Saharan countries	• Numbers of new graduates' secure positions as taxonomists or include taxonomic work in projects on their return to already held positions.	• Informal polls and examination of projects and publications of trained graduates	• Personal contact and internet searches of publications involving graduates.	• NORHED II grant is funded • Students show rea, continuing l interest in taxonomy following project end. • Universities and other Institutions of graduates support curriculum adjustments that include an increase in courses on taxonomy.
Objective 4: At least 4 new eco-friendly nature-based products for pest and vector control adopted for improvement of livelihoods of rural and wider community members in East Africa by the year 2025.					
4.1 At least 2 new potential products for mosquito control identified	• Two plant-derived insecticidal products	• Number of products produced and used.	• Records • Reports	• Reviews • Inspection	• Products are acceptable. • Favourable weather conditions.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
from plants based on efficacy, safety, and ease of application. 4.2 At least two plant-derived products for mosquito control formulated and packaged. 4.3. Community-based cultivation of selected insecticidal plants initiated. 4.4. Community-based production and use of plant-derived products for mosquito control initiated in at least one project site. 4.5. At least 1 PhD and 1 MSc students trained. 4.6. At least three papers prepared and submitted to international journals. 4.7. A plant processing facility for the community established	adopted for use in mosquito control by a local community by 2025. • Three papers or patents on potential mosquito control products published by 2025. • One prerational processing facility	• Number of community members using the mosquito control products. • Number of reports and publications. • Number of students trained. Number of processing facility established	• Journals index		• Funds are available.
Objective 5: Evaluation of the contribution of the gut microbiota to honeybees and stingless bees physiologies, nutrition, and resistance against natural pathogens and agro-chemicals.					
5.1. Characterization of the gut microbiota of feral honeybees in Africa. 5.2. Determine gut microbiota adaptability and flexibility to colonize different *Apis mellifera* subspecies.	• Understand the composition of the gut microbiota in *Apis mellifera* subspecies. • Understand human impact on the honeybee gut microbiota at the strain-level and functional diversity. • Establishment of a bacterial strain library from the honey bee gut for future research.	• List of bacterial species inhabiting the honeybee gut in Kenya. • Establishment of a gut microbiota laboratory. • Scientific publications • Establishment of international collaborations. • Number of graduated students.	• Project documents reports • Publications • Sequence data base • Bacteria strain library	• Future research • Data base for potential product development (probiotics, bio-reactors)	• African bee gut microbiota could be cultured in the lab as reported in other continents. • The full characterization of bacterial coding capacities and thus bacterial role in bee physiology, will need higher expertise and computational data power not present at the institute (need for international collaborations)
5.3. Characterization of the gut microbiota of at least 8 species of stingless bees at the metagenomic level.	• Establishment of a bacterial strain library from the stingless bee gut for future research. • Understand and characterized potential	• Establishment of a gut microbiota laboratory. • Scientific publications • Establishment of international collaborations.	• Project documents reports • Publications • Sequence database • Bacteria strain library	• Future research • Database for potential product development (probiotics, bio-reactors)	• African bee gut microbiota could be cultured in the lab as reported in other continents. • The full characterization of bacterial coding capacities and thus bacterial role in bee physiology, will need higher expertise and computational

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
	obligated symbionts for stingless bees.	• Number of graduated students.		• Contribute to determine the essential factors for stingless bee domestication and productive rearing.	data power not present at the institute (need for international collaborations)
5.4. Determine the effects of chemicals (pesticides, fertilizers, etc.) on bee gut microbiota tested	• Determine the toxicity levels of commonly used herbicides. • Determine if there are potential developments of gut microbiota resistance against these herbicides. • Establish the effect of these chemicals on the gut microbiota abundance and diversity. • Determine the metabolic pathways involved in chemical detoxification. • Understand how all these aspects listed above translate into detrimental effects on bee physiology.	• Scientific publications • Number of graduated students	• Project documents reports. • Publications • Herbicide database and their LD50 for the African honey bee. • Bacteria strain library • Database of bacterial metabolic pathways involved in detoxification.	• Future research • Database for potential product development (probiotics, bio-reactors, herbicide resistant bacteria)	• The full characterization of bacterial coding capacities and thus bacterial role in bee physiology, will need higher expertise and computational data power not present at the institute (need for international collaborations)
Objective 6: Increasing honey and silk production by 20% in selected African farming communities by 2022.					
6.1 Potential and healthy silk and bee races identified for enterprise development in Africa by 2022. 6.2 Healthy silk and bee races are distributed to 1,000 trainers for the farmer groups. 6.3 At least 5 PhD and 10 MSc students trained. 6.4 At least 50 peer reviewed papers and five books/proceedings published in international journals.	• 60% of the farmers use improved bee and silk races. • Development of strains and identification of hybrids with productive merit. • Establish germplasm for silkworm races in Africa.	• Number of farmers using improved races. • Disease resistant races selected. • Production hybrids breeds for silkworm selected • No. of thesis produced. • No. of manuscripts published.	• Morphometrics and DNA fingerprinting results. • Records by relevant Government Ministries/Departments (eg Livestock and Agriculture)	• Field surveys. • Online publication searches • Graduate Thesis copies	• Bee and silkmoth diseases under control.
6.5 Training material developed and training sessions held for 2,000 trainers.	• Knowledge of sericulture and apiculture is applied by	• Number of farmers trained. • Number of certificates (exam).	• Registry data. • Baseline surveys.	• Training Records. • Copies of Training manuals.	• Beneficiaries adopt value addition skills.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
	at least 750 farmer groups (each 50 to 100).	• Number of farmers applying their new knowledge.		• Project reports.	• Less than expected number of trainees with interest • Covid -19
6.6 Business model developed using value chain approach.	• Business model and business responsibility adopted by at least 400 farmer groups.	• Number of enterprises registered. • Private sectors working with farmer groups	• Relevant Government ministries, agencies and private sector.	• Survey. • Government and Community marketplaces records.	• Beneficiaries/private sector/stakeholder's willingness to support market-oriented values chains.
6.7 16 to 20 marketplaces (honey and silk harvesting, processing and selling units) established.	• 20% increase in honey and silk quantity by 2022.	• DC registry. • Production records.	• Records. • Bank statement of marketplace account. • Project reports	• Survey. • Inspection.	• Conducive weather. • No natural disaster (floods, drought, pests and disease outbreaks. • Beneficiaries own enterprises. • Stable markets for silk and hive products. • Government support and integration of silk and honey value chains in the National Development Plans.
6.8 Modern beehives supplied to farmers and rearing houses (silk moth) established.	• 500 beehives supplied to farmers by 2021.	• Project records.	• Registry of farmers. • Project reports	• Field evaluation in project areas	• Farmers are willing to adopt modern beekeeping. • Control standards are in place and operational.
6.9. Internal control system (ICS) training for 3,000 trainers conducted.	• Percentage of communities producing honey and silk to European Union (EU) standards increases from 20 to 30% by 2021.	• Honey and silk quality assessed and certified.	• Government standards agencies (Kenya Bureau of Standards, Institute for Market ecology, Switzerland).	• Laboratory test. • Market surveys	• Farmer communities are willing to go for organic certification. • Control standards are in place and operational
Objective 7: Integrative Pollinator-Plant Interaction Assessment of Ecosystem Service Diversity in Sub-Saharan Africa (JRS Biodiversity Foundation Project) by the year 2021					
7.1. Web-based platform (database) for Plant-Pollinator Interactions.	• Deepened understanding of plant-pollinator interactions for conservation of pollination services.	• Web-based platform (APPI) in usage.	• APPI platform, project technical report.	• Visit of website.	• Partnership with Upande Ltd (private sector partner)
7.2. Data collected and deployed in database for two ecosystems in Kenya.	• Deepened understanding of plant-pollinator interactions for conservation of pollination services.	• Number of data records deployed in database (10,000 interaction records).	• APPI platform, project technical report.	• Visit website.	• Weather conditions, security in field sites.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
7.3. Assess risks for common pollinator species using species distribution modelling.	• Assessment of risks for distribution due to climate change, land use change etc. to inform conservation measures.	• Species distribution models.	• Scientific publications. • Project technical report.	• Publication search. • Project report database.	• Weather conditions, security in field sites for field-based data collection. • PhD student in charge performs well.
7.4. Establish plant-pollinator networks for different land use types.	• Deepened understanding of plant-pollinator interactions for conservation of pollination services.	Plant-pollinator networks.	• Scientific publications. • Project technical report.	• Publication search. • Project report database.	• Weather conditions, security in field sites for field-based data collection. • PhD student in charge performs well.
7.5. Assess genetic diversity of pollinators using DNA barcoding.	• Deepened understanding of plant-pollinator interactions for conservation of pollination services.	• 300 molecular barcodes of bees provided.	• GenBank/iBOL database. • Scientific publication. • Project technical report.	• Data base search. • Publication search. • Project report database.	• Weather conditions, security in field sites for field-based data collection. • PhD student in charge performs well.
7.6. Capacity building of stakeholders in database usage.	• Increased uptake of database usage by other stakeholders.	• Data records on interactions deployed. • Database usage records (registered users).	• APPI database and database statistics.	• Database search.	• Lack of data to support database.
7.7. Capacity building for biodiversity bioinformatics for *icipe* staff.	• Independent database development and management at *icipe.*	• Number of staff to be trained in biodiversity databases.	• Project technical report.	• Project report database.	• Staff leaves *icipe.* • Dis-continuation of staff contract.
Objective 8: Evaluate the pollination efficiency of different stingless bee species in enhancing fruit quality and contribute in discriminating the African stingless bee species using molecular tools by 2021.					
8.1 Assess of pollination efficiency of 10 stingless bee species and African honeybees in three greenhouse crops in Kenya	• Pollination efficiency of seven stingless bee species and African honeybees assessed for strawberry crops in greenhouse in Kenya by 2024. • Pollination efficiency of seven stingless bee species and African honeybees assessed for bell pepper crops in greenhouse in Kenya by 2021. • Pollination efficiency of seven stingless bee	• Data on fruits quality and quantity records. • Pollinator-Nectar-dwelling micro-organisms data available for 1 tested crop. • A manuscript on watermelon pollination by stingless bees submitted to journals. • A manuscript on blue berry pollination by stingless bees submitted to journals. • A manuscript on strawberry pollination by stingless bees submitted to journals.	• Scientific publications. • Project technical report. • MSc thesis. • PhD thesis • Project technical report	• Field evaluation. • Publication search. • Project report. • MSc thesis • Field experimentation • PhD thesis • Msc thesis • Publications	• Conducive weather for bee to forage. • Emergency of crop pest and diseases. • Seeds of poor germination rates. • Covid 19 • Discontinuation of the student • Discontinuation of staff contract

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
	species and African honeybees assessed for watermelon crops in greenhouse in Kenya by 2021. • Report on plant-pollinator-microbe interaction bell pepper crop by 2021. • Msc thesis on pollination of watermelon by stingless bees by 2021. • Msc thesis on pollination of blue berry by stingless bees by 2022 • PhD thesis on pollination of strawberry by stingless bees by 2025	• One MSc student thesis on Blue berry pollination by stingless bees. • One MSc student thesis on watermelon pollination by stingless bees. • One PhD student thesis on strawberry pollination by stingless bees.			
8.2. Assess stingless bee species distribution using modelling technics.	• Report on factors determining stingless bee species distribution in Kenya established by August 2021. •	• One PhD thesis on species distribution models provided for Kenya. • At least one manuscript modelling destribution of stingless bee species prepared and submitted to journal.	• Scientific publications. • Project technical report.	• Field surveys. • Project report. • African stingless bee book.	• Bad weather not favourable to detect bee nest. • Security in field sites for field-based data collection. • Political situation is favourable. • Taxonomists' priorities change. • Kenyan authorities change their insect export policies. Covid 19
8.3. Assess genetic diversity of African stingless bees using DNA barcoding and morphometric analysis	• Wing geometric morphometric of African stingless bee species finalized by July 2021. • Molecular barcodes of African stingless bee species finalized by July 2021. • An additional rearing shade for demonstration established	• Wing geometric morphometric of African stingless bee species provided. • Molecular barcodes of African stingless bee species provided and uploaded sequences, voucher specimen images and trace files in Bold. • Booklet on African stingless bees provided.	• BOLD database. • Scientific publication. • Project technical report. • Morphometrics, DNA and microsatellites fingerprinting results. • African stingless bee book.	• BOLD Data base search. • Publication search. • Project report. • Laboratory analysis. African stingless bee book.	• Regional cooperation • Unfavourable Political situation.. • Covid 19 change in regional travel legislation due to Covid 19

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
	with colonized hives in the University of Kinshasa in DRCongo by June 2021 • An additional rearing shade for demonstration established with colonized hives in the KFS Isiecheno forest station in Kakamega, Kenya by August 2021	• A stingless bee demonstration site established in the University of Kinshasa DRCongo. • A stingless bee rearing demonstration site established in the KFS Isiecheno forest station in Kakamega, Kenya. • Manuscript on wing geometric morphometric of big and middle body size stingless bees by August 2021. • Manuscript on wing geometric morphometric of small body size stingless bees by August 2021. • Manuscript on DNA barcoding of African stingless bees by August 2021.			
8.4. Capacity building of stakeholders in meliponiculture	Training in Cameroun and DRcongo	2 training conducted in DRCongo and 1 in Cameroon by the year 2021	Project technical report.	• Project report	• Regional cooperation. • Political situation is favourable. • Covid 19 • Change in regional travel legislation due to Covid 19
8.5. Capacity building of university students on conducting pollination efficiency evaluation studies.	• Training of at least two Msc students and one PhD student	Msc and PhD thesis from students	• Project technical report.	• Project technical report. • Publication submitted	• Dis-continuation of the students. • Covid 19 • Change in regional travel legislation due to Covid 19
Objective 9: Generate 100,000 dignified and fulfilling employment opportunities for unemployed young women and men in honey and silk value chains and complementary income generating activities by 2024 (MOYESH program)					
9.1. Establish partnerships and identify and develop resources for scaling up beekeeping and silk farming enterprises to increase employment and learning opportunities for youths (PARTNERSHIP AND RESOURCES MOBILIZATION)	• Increased honey, hive products and silk production by youth enterprises	• Amount of honey, hive products, silkworm cocoons and silk yarn produced by the youth enterprises	• Baseline survey database. • Relevant Government offices and private sector partners.	• Targeted surveys • Stakeholder and youth interviews • Agreements signed with partners	• Willingness of youth, value chain actors and stakeholders to cooperate. • Security situation in target areas favourable to program implementation. • Political stability prevails • No major natural disasters, like drought, disease outbreak, massive pest attack

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
9.2. Link young men and women with financial service providers through digital financial services and business-to-business (B2B) linkages (FINANCIAL INCLUSION)	• Increased utilization of affordable financial services for the young men and women targeted by the program • Youth enterprises secure working capital through linkage with private actors (producers, processors, aggregators and exporters) • Increased utilization of digital and youth friendly financial products and services by young men and women • Youth mobilized saving and create funds for investment in beekeeping and silk farming or related businesses	• Number of youths that received credit services from financial service providers (MFIs and Banks) • Number of youth enterprises that accessed working capital through B2B agreements with private actors • Number of youths that used youth friendly financial products and services (saving, credit appraisal, mobile and agent banking services) • Amount of loans and savings mobilized through VSLA	• Baseline survey database. • Reports of relevant Government offices and private sector partners.	• Targeted surveys • Stakeholder and youth interviews	• Willingness of youth, value chain actors and stakeholders to cooperate. • Security situation in target areas favourable to program implementation. • Political stability prevails • No major natural disasters, like drought, disease outbreak, massive pest attack
9.3. Develop market linkages and youth-owned profitable beekeeping, sericulture and complementary enterprises (MARKET LINKAGES AND ENTERPRISES ESTABLISHMENT)	• Youth enterprises established and generate income in silk and honey value chains • Increased honey and hive products value addition and processing for better market value and quality • Increased silk value addition and processing for better market value • Increased income from complementary side businesses • Increased honey and hive products quality and residue analysis for export certification	• Number of youth enterprises that started generating income from silk, honey and related value chains • Volume of honey and hive products processed in the marketplaces • Volume of silk yarn and fabrics produced at the silk processing centers in kg • Amount of income received by youth from complementary side businesses • Amount of honey and hive products tested for export	• Training manuals. • Project documents, reports. • Publications. • Registry of youth.	• Field surveys. • Stakeholder interviews. • Network partners in collaborative agreements • Developed businesses / enterprises.	• Willingness of youth, value chain actors and stakeholders to cooperate. • Regional cooperation. • Adequate resource mobilisation. • Conducive weather. • Beneficiaries own enterprises.
9.4. Develop skills and capacity of youth and partners to undertake and manage successful and sustainable beekeeping and silk enterprises as	• Increased capacity of partners to support youth enterprises as well as complementary IGAs	• Percent of stakeholders reported improved capacity in providing technical support and training to youth to	• Training manuals. • Project reports, documents • Publications.	• Field surveys. • Stakeholder interviews.	• Willingness of youth, value chain actors and stakeholders to cooperate. • Regional cooperation.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
well as complementary activities (SKILLS CAPACITY DEVELOPMENT)	• Increased capacity of youth to establish and manage successful and sustainable beekeeping and silk enterprises as well as complementary IGAs • Improved youth business, entrepreneurship and soft skills to run successful enterprises	establish successful and sustainable enterprises. • Percent of youth reported improved technical skills and knowledge in beekeeping and silk farming activities • Percent of youth reported improved entrepreneurship, business and soft skills (soft skills score)	• Independent program evaluations • Registry of youth.	• Agreements signed with partners • Technologies adopted.	• Adequate resource mobilisation.
9.5. Develop and implement gender sensitive monitoring, evaluation and learning (MEL) system to guide decision making and facilitate learning (MEL)	• MOYESH MEL framework developed and made operational • Baseline data collected and baseline values and target established • Web based (digital) monitoring system established and made operational • Periodic monitoring conducted and evidence of progress or lack thereof documented and shared • Evidence of success, failure and lessons documented and shared • Midterm and end term evaluations conducted	• MOYESH MEL framework in place • Baseline survey report and completed M&E Matrix • Functional web based (MIS) monitoring system in place • Number of monitoring reports produced and shared • Number of case studies, success stories, technical studies and best practices produced and shared • Mid-term and final evaluations conducted, and reports made available	• Program documents (M&E plan, log frame, baseline database, etc.) • Program website • Program strategies, guidelines, roadmaps • Publications • Reports of independent program evaluations.	• *icipe* reports. • Program documents • Stakeholder reports. • Independent midterm and final program evaluations • Targeted surveys	• Willingness of youth, value chain actors and stakeholders to cooperate. • Regional cooperation.
9.6. Establish effective project coordination, partnerships and communication strategies for successful management and implementation of the program (COORDINATION AND IMPLEMENTATION SUPPORT)	• Program launching conducted at regional and federal levels • Program planning and progress review meetings conducted at national and regional levels • National and regional steering committee meetings conducted • Program communication plan developed and implemented	• Number of program launching workshops • Number of annual program review and planning meetings conducted • Number of regional and national steering committee meetings conducted • Program communication plan in place and under implementation • Number of communication outputs prepared and	• Minutes and proceedings of meetings • Program reports • Stakeholder / partner reports • Publications • Reports of independent program evaluations.	• *icipe* reports. • Program documents • Stakeholder reports. • Independent midterm and final program evaluations • Targeted surveys	• Willingness of youth, value chain actors and stakeholders to cooperate. • Regional cooperation.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
	• Program achievements and best practices documented and disseminated • MOYESH Program website designed and launched • Digital information exchange/sharing platform developed • MOYESH training manuals published and translated to regional languages • Program partners (Private and NGOs) identified and engaged • MOYESH Program technical and financial reports and monthly briefs prepared and submitted to the MCF • MOYESH Program Quarterly and monthly briefs prepared and submitted to the MCF and Program Management Committee	disseminated (leaflets, banners, etc.) • MOYESH Program website developed and functional • MOYESH digital information exchange platform developed and used to share information with youth and stakeholders • Number of training manuals published and translated to regional languages • Number of NGOs and private sectors that signed MoUs to support implementation of MOYESH Program • Number of Technical and Financial Reports produced and shared with the Foundation • Number of quarterly and monthly reports produced and shared with the MCF and Program Management Committee			
Objective 10: Investigate the ecology and evolution of sub-Saharan African stingless bees by 2025					
10.1. Analyse the physico- chemical and bifunctional properties of African stingless honey	• Physico-chemical composition of various African stingless bees known and published. • Biofunctional properties of various African stingless bees known and published	• One PhD staff trained • 2 publications	• Scientific publications. • Project technical report. • PhD thesis	• Field sample collection • Laboratory analysis • Project technical report. • Publication submitted.	• Regional cooperation. • Dis-continuation of the students • Political situation is not favourable in sampling countries. • Corona virus or any other human pandemic crisis • County authorities change their biological samples export policies
10.2. Compare physico- chemical and bifunctional properties of stingless bee honey from African, Asia and South America	• Chemical composition and bifunctional properties of various worldwide stingless bees known and published	• One PhD staff trained • 1 publication	• Scientific publications. • Project technical report. • PhD thesis	• Field sample collection • Laboratory analysis • Project technical report. • Publication submitted.	• Regional cooperation. • Dis-continuation of the students • Political situation is not favourable in sampling countries. • Corona virus or any other human pandemic crisis • County authorities change their biological samples export policies

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
10.3. Compare physico- chemical and bifunctional properties of stingless bee and honeybee *Apis mellifera* honey	• Chemical composition and bifunctional properties of stingless bees and honeybee known and published	• PhD staff trained • 1 publication	• Scientific publications. • Project technical report. • PhD thesis	• Field sample collection • Laboratory analysis • Project technical report. • Publication submitted	. • Regional cooperation. • Dis-continuation of the students • Political situation is not favourable in sampling countries. • Corona virus or any other human pandemic crisis • County authorities change their biological samples export policies
10.4. Determine host plants for pollen and nectar across stingless bee species and Agroecological zones,	• Primary and secondary nectar and pollen host plant known for different African stingless bees in different agroecological zones	• One PhD staff trained • 1 publication	• Scientific publications. • Project technical report. • PhD thesis	• Field sample collection • Laboratory analysis • Project technical report. • Publication submitted.	• Regional cooperation. • Dis-continuation of the students • Political situation is not favourable in sampling countries. • Corona virus or any other human pandemic crisis • County authorities change their biological samples export policies
10.5. Model the ecological niches of stingless bee species and their host plants under climate change scenario and land use/land cover change, based on existing species occurrence records covering most of sub-Saharan Africa	• Suitable niche for various stingless bee species identified in relation to host plant • Impact of land cover lost and climate change predicted for various stingless bee species	• One PhD staff trained • 2 publications	• Scientific publications. • Project technical report. • PhD thesis	• Field sample collection • Project technical report. • Publication submitted	• Dis-continuation of the students. • Corona virus or any other human pandemic crisis
Objective 11: Participatory beekeeping for ecological protection of Mangrove forests in Zanzibar (ZanBee) done by 2022					
11.1 To develop a mutual link between beekeeping and environment for improved honey production, through promotion of multipurpose and all-season nectar and pollen supply plants through community nurseries and training	• Increase to 25% of beekeepers engaged in other environmental activities • Increase in planting of multipurpose trees in area to 100 pieces (per beekeeping group) by project end • 1-2 different products derived from beneficial trees	• Number of beekeepers who are engaged in environmental activities • availability of forage plants over the whole year • Number of products derived from beneficial trees produced	• Technical report	• Socio-economic report incl. additional questionnaires	• Willingness of beekeepers to participate
11.2 To promote beekeeping and enhancement of honey production through practical beekeeping training, development of capacity for monitoring of honeybee health and product quality	• Increase of honey production by 500 kg per year (by 2022 compared to 2021)	• kg of honey produced • quality of honey produced • availability of information on bee health (provided by beekeepers)	• Technical report • Records (reports, notes) of beekeepers	• Socio-economic assessment (ex ante vs ex post)	• Good colonization rate of beehives and low absconding rate of bees • At least average weather conditions

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
	• Increase of high quality of honey produced by 80% of farmers • 50% of participating farmers keep records of the health of their bees			• Records (reports, notes) of beekeepers	
11.3 To increase incomes through improved market access facilitated through hive product diversification and value addition	• At least 20% of farmers increase price of their products during project period by 20% • At least 20% of participating farmers engage in hive product diversification • Linkages with at least 5 marketing partners established • 500 kg of honey sold	• level of honey & wax price • number of farmers diversifying their hive products • number of marketing partners • kg of honey sold	• Technical report	• Ex ante vs ex post assessment and additional questionnaires; • Marketing data by groups	• Willingness of farmers to engage in product diversification • Willingness of farmers to contact new customers • Farmers are willing to use methods of value addition
Objective 12 (Norad-CAP Africa): Increasing health and livelihood of target communities in Kenya by improving the knowledge on the use of social bees as key pollinators for crops and hive product production					
12.1 Assess of pollination efficiency of 7 stingless bee species and African honey bees yellow bell pepper crops and watermelons in Kenya	• Pollination efficiency of 7 stingless bee species and African honeybees assessed for pepper and watermelon crops in greenhouse by May 2021	• Data on fruits quality and quantity records. • A manuscript on watermelon pollination by stingless bees submitted to journal	• Scientific publications. • Project technical report. •	• Field experimentation • Publication search. • Project report. •	• Conducive weather for bee to forage. • Emergency of crop pest and diseases. • Seeds of poor germination rates. • Covid 19
12.2 Assess the quality of stingless bee honey produced by 6 stingless bee species of interest for honey production in Kenya	Quality of stingless bee honey produced from diverse agroecological zones of Kenya established and communicated by May 2021 •	• Data on quality of stingless bee honey available for Kenya. • Establish the physicochemical quality and bio functional properties of stingless bee honey from four agro-ecological zone in Kenya. • A manuscript on physicochemical quality and bio functional properties of stingless bee honey from four agro-ecological zone in Kenya submitted to journal	• Scientific publications. • Annual publication report of icipe • Project technical report. •	• Field collection of honey samples • Lab analysis • Publication search. • Project report. •	• Conducive weather for bee to forage. • Covid 19 • Some species not occurring in the sampling agroecological zones • Occurring species not having enough honey stored in their wild nest during field sample collection
	• Antibacterial and bio functional properties of stingless bee propolis from four agro ecological zone in	• Data on quality of stingless bee propolis available for Kenya.	• Scientific publications.	• Field collection of propolis samples • Lab analysis • Publication search.	• Conducive weather for bee to forage. • Emergency of crop pest and diseases. • Covid 19

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
	Kenya established and communicated by May 2021 •	• A manuscript on antibacterial and bio functional properties of stingless bee honey from four agro-ecological zone in Kenya submitted to journal	• Project technical report. •	• Project report. •	• Some species not occurring in the sampling agroecological zones • Occurring species not having enough propolis stored in their wild nest during field sample collection
12.3. Assess the botanical origin of stingless bee honey from 6 stingless bee species in Kenya	• List of plants utilised for honey production by stingless bees in four agro-ecological zone in Kenya established and communicated by May 2021 •	• Data on foraging plants of stingless bees available for some agroecological zones of Kenya. • A manuscript on foraging plants of stingless bees from four agro-ecological zone in Kenya submitted to journal.	• Scientific publications. • Project technical report. •	• Field collection of beebread samples • Lab analysis • Publication search. • Project report. •	• Conducive weather for bee to forage. • Emergency of crop pest and diseases. • Covid 19 • Some species not occurring in the sampling agroecological zones • Occurring species not having pollen stored in their wild nest during field sample collection
12.4 Assess impact of landscape on the stingless bee species diversity and nesting sites in Kenya (Taita and Makueni) and Ethiopia (Yabelo)	• Data on stingless bee species community and nest sites in Kenya (Taita and Makieni) and Ethiopia (Yabelo), •	• Data on stingless bee species community and nest sites in Kenya (Taita and Makieni) and Ethiopia (Yabelo), • One publication on landscape structure and species diversity and nest sites of stingless bees in Kenya (Taita, Makueni) •	• Publications • Project report	• Field survey • Literature review	• Covid -19 • Political conflict • Delay in research permits • Government restrictions to assess potential targeted sites •
12.5 Assess impact of landscape on forage resources selection by stingless bees in Kenya (Taita and Makueni) and Ethiopia (Yabelo)	• Taxonomy list of plants used by stingless bees for nectar and pollen in 2 Kenya sites and Yabelo in Ethiopia	• Data on stingless bee species community and nest sites in, Kenya (Taita and Makieni) and Ethiopia (Yabelo) • One publication on landscape structure and species diversity and nest sites of stingless bees in Kenya (Taita, Makueni) •	• Publications • Project report	• Field survey • Literature review	• Covid-19 • Political conflict • Delay in research permits • Government restrictions to assess potential targeted sites •
12.6 Environmental suitability mapping for foraging resources of stingless bees using remotely sensed variables in Kenya (Taita and Makueni) and Ethiopia (Yabelo)	• Mapping of distribution of stingless bees in regard to landscapes in 2 Kenya sites and Yabelo in Ethiopia	• Cartography of stingless bee species distribution and their foraging plants in Landscapes of 2 Kenya sites and Yabelo in Ethiopia	• Project report	• Field survey • Literature review	• Covid-19 • Political conflict • Delay in research permits •
12.7 Assess impact of landscape on stingless bee population dynamics and	• Suitable habitats for rearing stingless bees identified for	• Data on colony performance and productivity of specific	• Project report • Publication	• Field survey •	• Covid-19 • Political conflict

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
honey production in Kenya (Taita and Makueni) and Ethiopia (Yabelo)	2 Kenya sites and Yabelo in Ethiopia	species of stingless bees in in 2 Kenya sites and Yabelo in Ethiopia. • One publication on population dynamics and productivity of stinglees bee species in Taita and Makueni			• Delay in research permits • Vandalism of established meliponaries •
12.8 Assess swarm attraction methods of stingless bees based on traditional knowledge in Kenya (Taita and Makueni) and Ethiopia	• Technics to colonise hives	• One publication on stocking stingless bee colonies for meliponiculture	• Project report • Publication	• Field survey • Lab assay	• Covid-19 • Political conflict • Delay in research permits • Vandalism of hives set in the fields •
12.9 Training of stakeholders in meliponiculture for farm income diversification in Kenya (Taita and Makueni) and Ethiopia	• Stakeholders trained on modern meliponiculture.	• List of trainees • Number of establish rearing sites	• Project reports • List of trainees	• Training manuals	• Covid-19 • Political conflict • Lack of accessibility to virtual training by stakeholders
Broad objective 13: Develop insects for food, feed and other uses					
13.1. Specific objective: Insect feed for poultry, pigs and fish production in Sub-Saharan Africa.					
13.1.1. Cost-effectiveness and potential livelihood effects of insect-based feed technologies assessed through a gender lens along the value chain.	• The economic benefits of insect farming and insect-based feed for poultry, fish and pig production systems along the value chain determined by December 2020. • The long-term potential impact of insect-based feed technologies on food and nutritional security predicted by October 2020. • Economic viability of insect-based feed supply chain models to guide scaling up pathways by June 2021.	• At least 2 scientific papers on efficient insect mass-rearing techniques as affected by different agro-ecological zones. • 1 training guide on insect mass-rearing for feed with reference to production scales and gender developed. • 3 scientific publications on cost-effective organic fertilizer production through insect mass-rearing. • Stories of change focusing on experience and success from youth, men and women and other actors involved in the use of insect as feed documented. • At least 300 insect mass-rearing enterprises owned by women, men and youth established. • At least 10 feed producers integrating insect in their feed.	• Field survey reports. • Insect rearing data. • Training materials. • On-farm vibrant BSF colonies. • Project report. • Training manual. • Training register. • Publications. • Research data. • Evaluation reports from Kenya Bureau of Standards (KEBS).	• Field surveys. • Interviews and questionnaire. • Visits to partner companies. • Catalogue of pests and diseases. • Training evaluations. • Samples from the laboratory and market. • KEBS' assessments.	• Partners willing to use protocols for safe and mass production of BSF. • Political situation is favourable. • SMEs follow the postharvest rearing protocol to enhance BSF production.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
		• 2 MSc and 1 PhD student trained.			
13.1.2. Finetune and deploy rearing techniques under small- and medium-scale on-farm conditions to improve capacity planning to meet customer demand for insect-based protein and fertilizer.	• Traceability and capacity planning for reliable and timely meetings of customers' demands improved by 2021. • Quality organic fertilizer alongside high-yielding insect production developed and tested by September 2021. • Insect rearing under various on-farm conditions present, and its performance assessed based on different models (gender and age of farmer, scale of production, agro-ecology) by August 2021.	• Report produced on existing supply chain models for key commodities in Kenya; and on the role of youth, women and men in feed supply chains. • Publication on the gender differential economic benefits of insect farming and insect-based feed for poultry, fish and pig production systems along the value chain in Kenya. • Publication on the long-term potential impact of insect-based feed technologies on food and nutrition security in Kenya. • Report on economic viability of insect-based feed supply chain models in Kenya. • At least 2 MSc students trained.	• On-farm vibrant BSF colonies. • On-farm fertilizer report. • Training manual. • Publications. • Research data. • Product certification reports.	• Field surveys. • Interviews and questionnaire. • Visits to partner companies. • Catalogue of pest and diseases. • Training evaluations. • Samples from the laboratory and markets. • KEBS report.	• Partners willing to use protocol for safe mass production of BSF. • Political situation is favourable. • SMEs follow the postharvest rearing protocol for enhanced BSF production. • No adverse weather conditions prevail. • Farmer cooperate to provide land for planting trials. • Good seeds available for propagation.
13.1.3. Develop and test gender-inclusive insect feed supply models and build capacity along the value chain.	• Awareness creation. • Develop, test and compare different supply chain models linking insect production with feed manufacturing.	• Training manual developed. • At least 3,000 fliers produced and distributed. • At least 300 posters produced and distributed. • At least 6 training reports produced. • A curriculum on insect uses in animal feed developed. • At least 3,000 youth, men and women trained. • At least 10 entrepreneurs with successfully financed business models. • Report on existing supply chains in other commodities and their applicability to insect-based feed produced. • At least 5 radio and TV programs.	• Training workshop reports. • List of participants. • Flyer. • Posters. • Audiotape. • Video documents. • Publications. • Project reports. • Research data. • KEBS evaluation reports. • Theses. • Field survey report. • Pilot facilities.	• Value chain data collection and analyses. • Field surveys. • Key informant interviews with stakeholders.	• Farmers and other stakeholders are willing to cooperate. • Stable political situation in the region. • BSF available, and various rearing and processing techniques developed. • Feed millers' willingness to purchase insect-based products from producers.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
Specific objective 13.2: Testing business models for scaling insect-based protein feed for use in poultry farming and aquaculture in Kenya.					
13.2.1 Markets and marketing channels for insect-based protein feed using different business models developed.	• Identify and adapt potential business models for insect-based protein for feed in poultry and fish production. • Map the potential insect-based protein feed supply chains. • Establish and monitor the linkages between insect-based protein feed value chain actors. • Work with the private sector partners to support various components, including training, financing, and awareness creation. • Develop insect-based protein feed production and marketing information exchange platform to link actors along the value chain.	• Cost-effective and suitable commercial models identified and adapted for use of insects as feed. • Supply chains model for commercial production of insects documented. • Out-grower models utilizing insect for feed by farmers and private sectors established. • Private sector feed millers subcontract entrepreneurs and contribute to the training and awareness campaigns of BSF production. • Pre-financing for different needs in the production system documented. • SMEs develop outgrower models for sourcing insects from farmers/cooperatives and established market linkages with feed processors.	• Databases in public/institutional data repositories. • Project reports. • Publications/journal websites. • Policy briefs. • Training reports. • Participant list. • Manuals, posters and leaflets. • Student theses.	• Field experiments. • Socio-economic survey. • Desk studies. • Workshops. • ToT activities. • Market surveys. • Consumer surveys.	• Respondents' willingness to give information. • Policy makers willing to attend workshops and facilitate standard development and approval. • Stable political situation in the region.
13.2.2 Transfer and promote insect-based protein feed technologies among the various actors along the value chain.	• Establish BSF rearing facilities for demonstration and training on best practices related to production, processing and packaging. • Provide starter kits for production of insect-based protein. • Develop and disseminate, production protocols, training and outreach materials to sensitize and create awareness on insect-based protein feed. • ToT workshops on all aspects of the project outputs.	• Simple and cheap mass production technology with high potential for scale at the farm and SME levels established. • The most effective technologies for different commercial models documented. • The constraints/challenges of BSF production and options/challenges documented. • At least 200 entrepreneurs and start-ups have access to proven low-cost technologies. • At least 200 farmers adopt the technology of mass production of BSF for feed on-farm.	• Publication. • Project reports. • Research data. • Web resources. • KEBS evaluation reports. • Theses. • Field survey reports.	• Lab analyses and surveys. • Experimental data. • Data collection and analyses. • Field surveys. • Key informant Interviews with food traders.	• Farmers willing to cooperate. • Stable political situation in the region. • BSF available, and various rearing and processing techniques developed. • Feed millers' willingness to purchase insect-based products.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
13.2.3 and adoption of insect-based protein feed enterprises generated.	• Establish baseline and end-line data. • Optimize modular insect production systems for scaling, based on stakeholder feedback, and monitor for product quality and safety. • Assess the household level socio-economic benefits of insect-based protein feed farming and formulation among millers and farmers in the poultry and aquaculture industry. • Assess the potential for employment generation and country level economic benefits of insect-based protein feed for poultry farming in Kenya.	• Develop a business case for production of insect for feeds via the different models and make recommendations on the most viable business models. • Develop and distribute an easy-to-use manual for setting up of successful insect farms with details on costing. • At least 2,500 metric ton of insect-based protein produced and utilized for on-farm trails. • At least 3 optimal facilities for effectively scaling out on-farm production of BSF established. • Nutritional and safety qualities of BSF reared on various substrates under different production models compared to laboratory reared BSF. • At least 200 farmers recruited to participate in on-farm assessment and performance of insect-based protein feed on poultry and fish in target locations. • Nutrient quality established of formulated feeds produced by private feed millers to meet the nutritional demand of poultry and fish for optimal on-farm productivity. • Establish the socio-economic benefits of insect-based protein farming and feed formulation in poultry and aquaculture production by June 2021. • Establish the viability of insect-based protein enterprises for job creation among youths and women by June 2021.	• Publication. • Project reports. • Research data. • Web resources. • KEBS evaluation reports. • Theses. • Field survey reports.	• Lab analyses and surveys. • Experimental data. • Data collection and analyses. • Field surveys. • Key informant interviews with feed millers.	• Farmers and other stakeholders are willing to cooperate. • Stable political situation in the region. • BSF available and various rearing and processing techniques developed. • Feed millers' willingness to purchase insect-based products.
Specific objective 13.3: Systematic review of the state of research, product development and utilization of the long-horned grasshopper *Ruspolia differens* in Africa.					

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
13.3.1 Expert review and documentation of past and current research and development initiatives related to *R. differens*.	• Scientific and technical report on the state of research on *R. differens* in Africa completed.	• Draft scientific publication on the state-of-art of *R. differens* research and product development in Africa.	• Workshop report. • Review publication.	• Participant lists. • Expert review. • Focus group interview. • Data collection.	• Experts approves their participation.
13.3.2 Organize a stakeholder validation workshop in Kampala, Uganda.	• Evaluate expert reviews from stakeholders of *R. differens* value chains.	• 1 workshop organized in Uganda with stakeholders drawn from 5 different countries.	• Meeting report.	• Focus group interview. • Data collection.	• Partners willingly accept to participate.
Specific objective 13.4 : INSect-based agriBIZiness for sustainable grasshopper and cricket production and processing for food in Kenya and Uganda (INSBIZ)					
13.4.1. Market potential and market performance of insect-based food products assessed.	• Informed investment in insect-based food product commercialization increased by 2022	• At least two private sector players invest in insect-producing agro-businesses in Kenya and Uganda by 2019 • Market potential for grasshopper and cricket products in Kenya and Uganda established by 2018 • Market performance (penetration and cost-benefit performance) for grasshopper and cricket products in Kenya and Uganda established by 2020	• Company investment reports • Field survey reports • Publications • Farmer interviews • Domestic and export agro-statistics • Project reports	• Field surveys • Interviews and questionnaires • Visits to partner companies • Field data, secondary data collection • Developed market places	• Key informants willing to coorperate • Partners willing to coorperate in testing the insect-based food products • Permission granted by the bureau of standards in both countries. • Stable political situation in the region
13.4.2 Mass rearing protocols for crickets and grasshoppers adapted, piloted and up scaled	• Safe protocols for cricket and grasshopper rearing established widely adopted at various scales by 2022	• At least two SMEs mass rearing crickets and grasshoppers in Kenya and Uganda by 2020 • Rearing facilities for grasshoppers and crickets established and active insect rearing activities initiated by 2018. • At least two SMEs use the protocol and tools for safe crickets and grasshoppers mass rearing by 2018. • Protocols for healthy insect rearing documented by 2018 • Post-harvest protocols for cricket and grasshoppers under SMEs rearing and	• Field survey reports • Catalogue of pest and diseases • Insect rearing data • Training materials • Company investment reports • Vibrant colonies • Project report • Training manual • Training register • Publication	• Field surveys • Interviews and questionnaire • Visits to partner companies • Catalogue of pest and diseases • Training evaluations • Samples in laboratory and on the market • Bureaus of Stadandard's assessments	• Partners willing to use protocol for the safe and mass production of crickets and grasshoppers • Political situation is favourable • Key potential diseases and pests in target areas occur during project period and mitigation strategies found. • SMEs follow the post-harvest rearing protocol to enhance production.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
		trading conditions documented by 2018. • Insect based products commercialized are maintained under safe conditions by 2019. • Well packaged insect-based food products on the market by 2019. • Regional large-scale retailers commercializing insect-based food by 2020	• Research data • Web resources • Bureaus of Stadandard's evaluation reports •		
13.4.3. Ready-to-eat whole insects, insect flours for use as ingredients in food preparation developed and characterized, and insect-enriched porridge flours and cookies processed	• Adoption and use of insect-based food standards in Kenya and Uganda and increased consumer confidence in insect-based products by 2022	• At least two food-based SMEs produce and commercialize insect-based food by 2019. • At least two safely packaged insect products available on the market by 2019 • Effect of various rearing and processing conditions on nutritional characteristics of crickets and grasshoppers documented by 2018 • Insect-based products for women of reproductive age and five years old children or below developed and commercialized by 2019. • Insect based novel food available on supermarket shelves by 2020.	• Publication • Project reports • Research data • Web resources • Bureaus of Stadandard's evaluation reports • Theses • Field survey reports	• Lab analyses and surveys • Experimental data • Data collection and analyses • Field surveys • Market surveys • Consumer surveys • Key Informant Interviews with food traders.	• Supermarkets willing to sell • Costumers identify advantages in purchasing products marketed • Stable political situation in the region • Cricket and grasshopper available and various rearing and processing techniques developed • Consumers' willingness to purchase insect-based products
13.4.4. Favourable enabling environment for insect-based food through policy, advocacy and awareness creation established	• High consumer Acceptability for the insect-based products in Kenya and Uganda by 2022	• Policy briefs, advocacy and awareness creation materials established by 2019. • Insect based food standards developed and approved in both countries by 2020. • At least three workshop reports documented by 2019 • At least one policy brief on food standard development documented by 2019.	• Project Reports • Workshop reports • Publications • Policy briefs • Standards • Radio programs • Exhibitions reports	• Market surveys • Consumer surveys • Key Informant Interviews with policy makers and food traders. • Exhibitions • Workshops	• Consumers' willingness to give information, attend exhibitions and listen to radio programs • Policy makers willingness to attend workshops and facilitate standard development and approval. • Stable political situation in the region.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
		• Insect-based food advocacy materials developed by 2018. • At least 2 radio programs held by 2019. • At least one policy briefs developed on insect-based food by 2018. • At least two promotion materials disseminated on insect-based novel foods by 2019. • At least 2 exhibitions of insect-based food products done by 2020.			
Specific objective 13.5: Promotion of insect meal Commercial Production in Rwanda.					
13.5.1 Orientation and stakeholder workshop.	• Stakeholder meeting with the Government of Rwanda (GoR), feed companies and BSF companies. • Recruitment of MSc students and technical staff. • Learning trip to *icipe* of 5 Rwandan BSF company members.	• 2-3 stakeholder meeting organized by end of March 2021. • 1 MSc student and 1 technical staff recruited by March 2021. • Organize 3-4 days virtual training and field visit to insect rearing facilities of selected companies in Rwanda by March 2021.	• Inception meeting report. • Training report. • MSc theses	• Thesis. • Meeting minutes and attendance sheet. • Signed contracts with staff. • Field visits to other farmers.	• Participants' willingness to attend workshop. • Companies cooperate.
13.5.2. Work with selected BSF companies to develop substrate rearing and formulation.	• 3-4 BSF Rwandan companies to finalise their plans. • Orientation visit to selected Rwandan BSF companies. • Optimization of the rearing parameters and techniques standardized for the development of mother colonies with BSF companies. • Nutritional and bioactive compound profiling on various substrates.	• At least 3 companies selected, with finalized workplan and rearing parameters for mother colonies by June 2021. • Establish the nutritional profile of BSF reared on various substrates by August 2021.	• 3-4 BSF companies have their concepts and financial plans submitted to IMSAR. • Field reports. • Data on rearing. Parameters and production conditions. • Data on substrate quality.	• Lab analysis. • Field trials. • Training workshop.	• Companies willing to adopt innovative technologies for BSF mass production.
13.5.3 Work with the GoR.	• Meetings with RAB, FDA and other key GoR bodies.	• Work with GoR to get permit by June 2021.	• Assessment reports. • Workshops and meetings.	• Meeting minutes and attendance sheet.	• GoR's willingness to facilitate permit for importation of insects.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
	• Identify relevant areas for these agencies, warranting support.				
13.5.4. Provide support to relevant public sector agencies on insect feed related policy and regulations instruments.	• Develop draft insect feed regulations and standards with GoR. • Develop a risk report on heavy metals, pesticide residue, mycotoxins and other toxin risks, and microbiological safety.	• A draft standard on the use of insects in animal feed by September 2021. • Information of risk and safety assessment by October 2021.	• Draft regulations. • Data on contaminants and mitigation.	• Workshops. • Lab reports.	• Rwanda Bureau of Standards is ready to cooperate. • Reagents for analysis readily available.

CAPACITY BUILDING AND INSTITUTIONAL DEVELOPMENT at *icipe*

1. Overview of Activities

Building capacity of people and institutions to respond to the arthropod-related development needs of Africa has been a major commitment of *icipe* since its establishment in 1970. Capacity Building and Institutional Development (CBID) is achieved through *icipe's*'4-H' research portfolio in Human Health, Animal Health, Plant Health and Environmental Health. *icipe* offers high-level training at postgraduate and postdoctoral levels to develop scientific expertise and leadership within an array of partnerships with African and non-African universities, research organisations, NGOs and the private sector in the majority of Africa's states. Through training and the development of partnerships, the CBID programme at *icipe* strengthens African research and training capacities in insect and related sciences at national and regional research and higher education institutions.

- A key focus of *icipe*'s CBID programme is the *postgraduate (MSc and PhD) training* of researchers, primarily from across SSA to acquire the skills and research experience in insect and related sciences to engage effectively in science-led development through equitable collaborations with peers in SSA and elsewhere. The Postgraduate trainees are recruited through either The African Regional Postgraduate Programme in Insect Science (ARPPIS; which supports African PhD students with external scholarships and *icipe* project funding and enrolled at African universities, to pursue all their research at *icipe*) or the Dissertation Research Internship Programme (DRIP; which supports, mainly through project funding, PhD and MSc students of any nationality enrolled in African or non-African universities to pursue all or part of their research at *icipe*). Annually, *icipe*'s 4-H themes host at least 150 MSc and PhD students at various stages of their research.
- The *icipe Postdoctoral Fellowship Programme* provides opportunities for doctoral graduates to undertake research at *icipe* to pursue high-level research projects, acquire project funding, develop collaborative research programmes, and develop their leadership skills and careers. The programme has approximately 12-15 Postdoctoral Fellows at any one time.
- *icipe* also offers a *Science Internship Programme*, primarily targeting bachelor's undergraduates and graduates, to gain research experience in an international research environment.
- *Training courses and workshops. icipe* provides an array of training courses and workshops to give students and early career researchers the skills required for research and professional development, including science paper writing; grant writing; communications; information literacy; research integrity; research methods, statistics and data management; gender inclusiveness in research; and social sciences. Additionally, *icipe*'s research projects hold numerous non-degree professional development courses and workshops for their stakeholders, including researchers, mid-level practitioners and extension workers.
- *Partnerships.* CBID develops and maintains partnerships for training and capacity building. For example, *icipe* has strategic partnerships with universities within and outside of Africa, that provide experts for co-supervision of postgraduate students. Universities also monitor the quality of student research, and ensure that the students do meet the requirements for obtaining the degree. *icipe* also develops partnerships with universities to train their staff and postgraduate students. Other partnerships are developed for training courses and workshops.

2. Goal and Broader Objectives

The overall goal of the CBID programme is to continue to strengthen African universities' research capacity and research-based knowledge in insect science for food and health, and to ensure that partner institutions have capacity to independently undertake research training and

conduct high-quality, locally- and regionally-relevant research that delivers on-the-ground impact to poverty reduction and sustainable development in Africa.

The specific objective of the programme is to increase the number of high-quality researchers and middle level practitioners that are required to respond to arthropod-related research and development challenges in Africa by 2025.

3. Strategic Outlook (2021 to 2025)

Postgraduate (MSc and PhD) training of researchers, primarily from across SSA to acquire the skills and research experience in insect and related sciences to engage effectively in science-led development through equitable collaborations with peers in SSA and elsewhere.

icipe's long standing commitment to regional human capacity building and institutional development continues to expand: *icipe's* coordinating role in the PASET-RSIF programme will be a major growth area for *icipe* over the next five years. Further details of the PASET-RSIF RBM are given elsewhere.

CBID will support institutional development in an expanded outreach into West and Southern Africa. This will entail building capability in selected centres in those regions ('centres of excellence') and providing training at postgraduate and postdoctoral levels for their staff, with a focus on arthropod research for development. Together, this will build a critical mass of expertise and capabilities at these centres. This will require additional funding which targets capacity building in those regions.

Gender equality is among *icipe's* key values and is central to its strategic objectives. CBID will strive to achieve that equity by empowering women in all its capacity building initiatives.

4. Specific Future Thrusts

Gender equality in capacity development at *icipe* will be pursued in three ways:

i. Gender equality in the intake and advancement of MSc and PhD students, Postdoctoral Fellows, and Science Interns;
ii. Ensuring gender awareness and gender capacity in partners that are part of technology development and transfer; and
iii. Where needed, ensuring that women, men, and youth, as project beneficiaries, all have opportunities to receive appropriate training.

Support institutional development in an expanded outreach strategy into West and Southern Africa.

Develop and strengthen partnerships with key universities and capacity building partners for postgraduate programmes and institutional development.

Diversify and increase funding for postgraduate and postdoctoral programme.

Strengthen institutional capacity through the extensive capacity of the *icipe* alumni network.

Capacity Building and Institutional Development Results Based Management (RBM) Rolling Framework

Output	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
Objective: Increase the number and quality of researchers and middle level practitioners required to respond to arthropod-related research and ASET development challenges in Africa by 2025.					
1. Between 2021 and 2025, (a) 150 PhD and 150 MSc postgraduate students (at least 40% women) representing at least 18 sub-Saharan Africa nationalities in all sub-regions, at various stages of their postgraduate programme, conducting all or part of their research at *icipe* in arthropod and related sciences; (b) 200 PhD students in the Regional Scholarship and Innovation Fund project (at least 40% women), representing at least 18 sub-Saharan Africa nationalities in all sub-regions of SSA, at various stages of their PhD program at RSIF African Host Universities, conducting research in various ASET fields.	• At least 95% of students complete postgraduate training. • At least 75% of PhD students who complete their training each year during 2021–2025 contribute to research, development and higher education in Africa, dealing with reducing poverty, improving food and nutritional security, improving human, animal and environmental health; and work in Universities, National Research Systems, sub-Regional Organisations (SROs), International Research Centres (IRCs), and the private sector in Africa. • At least 50% of MSc graduates trained at *icipe* continue a career in R&D or higher education.	• Number of PhD and MSc students in the *icipe* postgraduate programmes at various stages of training, and number completing training with *icipe*, each year during the period 2021-2025. • Number of women in the programme each year. • Number of African countries represented in the postgraduate programmes each year. • Number of scientists trained at *icipe* and RSIF African Host Universities engaged in research, development and higher education in Africa. • Number scientists trained at *icipe* and RSIF African Host Universities leading research and development projects or playing a leading role in higher education in Africa. • Number of research activities/projects implemented in African institutions by scientists trained at *icipe* and RSIF African Host Universities during 2021-2025. • Number of graduates with positions of leadership in public & private organisations/enterprises in Africa.	• *icipe* and RSIF student databases • Student annual reports • Internet • Tracer studies conducted through email and surveys. • Ad-hoc interviews. • Scientific publications	• Review of *icipe* student database and annual reports • Requests for information from *icipe* alumni through online surveys, emails and interviews. • Internet searches, including searches of scientific social media such as Research Gate • Publication database searches, including Google Scholar and Scopus.	• Continued availability of icipe project funds and postgraduate scholarships for training at *icipe* • Continued availability of opportunities and funds at NARS, RECs, SROs, international centres, universities in Africa for R&D and higher education • Continued availability of RSIF funds for PhD training

Output	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
2. Dissemination of research results by *icipe* postgraduate students through 400 scientific publications (including theses, book chapters, peer-reviewed scientific papers, conference abstracts and proceedings, training brochures and manuals, policy documents, in print and online media) in the period 2021-2025	Research results disseminated in relevant formats at scientific community and policy maker levels	• Number of publications that result from research conducted by students at *icipe* (theses, book chapters, peer-reviewed papers, conference abstracts and proceedings, training brochures and manuals, print and online media). • Number of students contributing to policy documents. • Quality and relevance of *icipe* led-research results shared with scientific community determined by the number of citations in peer-reviewed publications. • Number of students participating in scientific meetings/conferences	• *icipe* Information Resource Centre (IRC). • Google Scholar • SCOPUS • University information repositories • Email questionnaires • Citation indices • Trip reports	• Search publication and theses databases at *icipe*, Universities, Google Scholar, SCOPUS • Review email questionnaire responses and trip reports • Query citation indices	• Continued availability of funds for scientific publications and attendance at scientific conferences
3. Career development opportunities for at least 20 early career postdoctoral fellows implemented during the period 2021-2025	• At least 75% of postdoctoral fellows and visiting scientists on completion at *icipe* proceed to contribute to research, development and higher education in Universities, NARS, SROs, IRCs, and the private sector in Africa each year during the period 2021-2025. • At least 50% of postdoctoral fellows attract competitive research grants during their tenure at *icipe.* • At least 50 scientific publications in peer-reviewed journals are published by postdoctoral fellows and visiting scientists during the period 2021-2025.	• Number of postdoctoral fellows. • Number of grants applied for and received by icipe postdoctoral fellows each year. • Number of postdoctoral fellows trained at icipe contributing to research, development and higher education in Africa. • Number of research publications in peer-reviewed journals. • Numbers of postdoctoral fellows supervising postgraduate students as primary or secondary supervisors.	• *icipe* postdoctoral fellow database • Project documents, reports. • Publication databases • *icipe* grant database • Surveys, emails, internet	• Review documents, reports, databases • Conduct surveys • Emails • Internet searches	• Availability of continuous funding to *icipe* programmes and projects to support postdoctoral fellowships and the students they supervise • Relevant grant calls are available each year

Output	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and Assumptions
	• At least 50% of postdoctoral fellows at icipe supervise PhD and MSC students as primary or secondary supervisors.				
4. 200 Research Interns (at least 40% women) trained during the period 2021-2025.	• At least 50% of trained research interns progressing to higher education, research and development careers each year during the period 2021-2025.	• Number of interns trained. • Number of women in the programme each year. • Number of research interns progressing to higher education, research and development careers	• *icipe* student database. • Internship reports. • Surveys, emails, internet	• *icipe* student database searches • Review intern reports • Conduct surveys • Email communications • Internet searches	• Availability of continuous funding to *icipe* R&D programmes to support research internships
5. 2000 researchers, mid-level practitioners and extension workers from 30 national systems in Africa trained in non-degree professional development courses during the period 2021-2025.	• At least 50% of trained researchers, mid-level practitioners and extension workers applying acquired knowledge and expertise in Africa each year during the period 2021-2025.	• Number of training courses. • Number of and type of trainees. • Number of organisations benefiting from training • Number of trainees applying acquired knowledge and expertise in Africa	• Training reports • Training follow up by email and online surveys	• Review reports, email follow up, and surveys	• Trainees respond to information requests. • Institutions where trainees apply knowledge have sufficient funding to support the work.
6. At least 10 capacity building activities developed with national and regional research and higher education institutions during the period 2021-2025.	• Research and training capacities strengthened at national and regional research and higher education institutions through the development of partnerships with *icipe*.	• Signed MoUs and collaborative agreements with partners. • Number of collaborative capacity building activities started with national and regional research and higher education institutions.	• MoUs • Project and training reports • Mission reports	• Review MoUs and reports	• Regional cooperation. • Adequate funding at icipe and partner organisations for collaborative capacity building activities.

BIORESOURCES INNOVATIONS NETWORK FOR EASTERN AFRICA DEVELOPMENT (BIOINNOVATE AFRICA) PROGRAMME

1. Overview

BioInnovate Africa (BA) is a regional initiative established in 2010 with support from the Swedish International Development Cooperation Agency (Sida). It is managed by and implemented as a Programme of the International Centre of Insect Physiology and Ecology (*icipe*) based in Nairobi, Kenya. BA currently operates in six eastern African countries, namely **Burundi, Ethiopia, Kenya, Rwanda, Tanzania, and Uganda,** where it assists these countries to build sustainable bio-economies based on revolutionary advances in bioscience and engineering, thereby diversifying sources of growth for the region's population.

BA supports scientists, researchers and innovators in the region's universities, research institutes and private firms to strengthen their capacities for linking biological based ideas, inventions and technologies to business and the market. Such links do not only enable translation of research outputs to innovations (goods and services) for societal use, but also expands opportunities to create jobs, increase household incomes and reduce poverty in a sustainable way.

In the current phase of BA, (2016-2021), 20 regional innovation projects are being supported under three thematic areas, viz; a) value addition to agro-produce; b) agro-waste/bio-waste conversion; and c) bio-economy policy analysis. These projects comprise scientists, business people and government officials working co-creatively with the aim of moving technologies to market using appropriate business models and fostering the development of a regional bio-economy strategy for eastern Africa. Ongoing projects include research and innovation activities involving: (i) green chemicals, (ii) post-harvest management, (iii) biological waste conversion, (iv) crop value added products, (vi) insect proteins for food and feed, (vii) food systems, (vIII) biofuels, and (ix) biofertilizers. Additionally, in response to COVID-19, BA is supporting scientists in its network to implement five (5) innovative research ideas in diagnostics, data science and plant-based extracts in eastern Africa.

2. Goal and objectives

The goal of BA is for universities, research institutes and firms in eastern Africa to actively translate innovative biological based ideas, inventions and technologies into business prospects, thereby contributing to improved productivity (and hence living standards) of smallholder farmers and communities in eastern Africa.

In 2021 – 2025, BA will contribute to diversifying sources of growth in eastern Africa based on biological resources in an inclusive and sustainable way.

The key objectives will be to:

a) Develop and scale up value added products from biological resources. Scientists from the public sector (universities and public research organizations) working collaboratively with the private sector will be supported to develop value added products from renewable bioresources.
b) Create new business prospects based on renewable biological resources. Entrepreneurial scientists will be supported to establish new businesses based on renewable biological resources through professional business incubation.
c) Support the development of local innovation ecosystems. Organizations that will be selected to implement a BA project will also receive support for local innovation ecosystem strengthening.

3. Strategic outlook (2021 to 2025)

Over 65% of the population in eastern Africa depend directly on biological resources for food, fuel, medicine and other uses. They use these resources in their raw form. Significant portions

of the bioresources are disposed as biological waste. Scientists and engineers in universities, research institutes and firms can find ways of adding economic value to these resources. By adding value, numerous other uses of the biological resources can be found, e.g. bio-waste can be turned into biofertilizers and energy and high value green chemicals can be processed. These new uses bring new business prospects and jobs, thus diversifying the economy. Farmers who produce most of the biological resource can be linked to new value chains that demand their produce. BA will enable scientists in the region to use their scientific knowledge in creative ways to add economic value to biological resources. Scientists, industry people and government officials will be supported to work collaboratively and co-creatively to find solutions to pressing development challenges of the region. Additionally, BA will offer a platform for scientists and business owners to work with their counterparts in other countries. This helps in regional integration, and also promotes regional investment and trade. BA's intervention will be inclusive, and should promote the development of sustainable bio-economies in eastern Africa.

4. Specific future thrusts

a) *Innovation:* BA will support development of biological based products (i.e. goods or services) that are innovative, make a convincing business case, and have clear environmental and social benefits. The products may be new or improved versions of existing ones; and may also involve adaptation of new practices in organizations and firms.
b) *Regional integration:* BA will continue to work across countries in an interdisciplinary fashion promoting regional integration, which is essential for addressing regional challenges. Regionality is BA's unique attribute. It opens up new opportunities for mobility, investment and trade. Partners shall work across countries with at least three partners in different countries.
c) *Sustainability:* Ensuring environmental sustainability shall be a key aspect of all BA activities. Actions shall contribute to reducing greenhouse gas emissions, and shall be consistent with the global SDGs of 2030.

BioInnovate Africa Programme Phase II Results Based Management (RBM) Rolling Framework

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
Project purpose: Universities, research institutes and firms in eastern Africa actively translate innovative biological based ideas and inventions into business prospects					
Specific Objective 1: Develop value added goods and services from biological resources					
1. Innovative value-added goods that create value for customer segments in rural and urban communities.	Enhanced capacity of Eastern African universities and research organizations to translate modern biosciences into innovations targeting smallholder farmers and agro-process enterprises in the region	- % change in no. of bioscience value-added goods at different levels of development (undergoing value addition, ready for market, market tested)	Project progress reports	Review of project reports	- Value-added goods are socially and economically sustainable. - Partners are committed to promoting bioscience value-added goods
2. Innovative value-added services that create value for customer segments in rural and urban communities.		- Number of bioscience services at different levels of development (undergoing value addition, ready for market, market tested)	Project progress reports	Review of project reports	- Value-added services are socially and economically sustainable. - Partners are committed to promoting the bioscience value-added services.
3. Bioscience knowledge that addresses the needs of smallholder farmers and agro-processors developed.		- % change in no. of bioscience ideas emerging from the projects - Number of intellectual properties (including patents) acquired at different levels of product development i.e. applied for, awarded, or in gazette	- Universities, firms, and research institution reports - Farmers and agro-processors	Review of six-monthly project reports	- Funding opportunity is flexible and embeds new research ideas into projects.
Specific Objectives 2: Create new business prospects based on renewable biological resources					
4. Bio-based business models that help smallholder producers, and agro-processors to gain a competitive advantage in national and regional markets.	Increased linkages between research institutions, universities, and the private sector (including investors)	- Number of validated bio-based business models	Project progress reports	Review of project reports	- Business models for bio-based enterprises are feasible and scalable in the region. - The policy environment fosters academia-industry collaboration.
5. Spin-off companies are developed and supported.		- Number of company registration certificates	Project progress reports	Review of project reports	

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
6. Pipeline investors in biobased goods and services are linked to the programme		- Number of investor pitches and meetings organized with potential investors.	Project progress reports	Review of project reports	- Investors increasingly seek new opportunities in bio-based goods and services.
Specific objective 3: Support the development of local innovation ecosystems					
7. Institutional innovation frameworks are developed.	Improved prioritization and coordination of policy responses to promote bio-based innovation and entrepreneurship	- Number of institutional innovation policies drafted - Innovation/technology transfer offices established	Project progress reports	Review of project reports	- There is commitment from local institutions to develop innovation frameworks.
8. Networks and partnerships developed		- Number of contracts and/or agreements signed to engage with various stakeholders	Project progress reports	Review of project reports	- Governments in the region promote partnerships and networks for promotion of bioscience innovations
9. Relevant policy options to support scientists in their effort to promote bioscience innovations for smallholder farmers and agro processors evaluated		- Strategies/policies put in place by governments to support and promote biosciences innovations. - Enabling regulations put in place by governments to support and promote biosciences innovations.	Project progress reports	Review of project reports	- Technical capacity to undertake policy analysis for promoting bioscience innovations exists in the region.

PARTNERSHIP FOR SKILLS IN APPLIED SCIENCES, ENGINEERING AND TECHNOLOGY (PASET) - REGIONAL SCHOLARSHIP AND INNOVATION FUND (RSIF)

Preamble

The Regional Scholarship and Innovation Fund (RSIF) is the flagship initiative of the African government-led Partnership for skills in Applied Sciences, Engineering and Technology (PASET)[1]. RSIF aims to address fundamental gaps in skills and knowledge needed for increasing the use of science, technology and innovation for sustained economic growth in SSA. RSIF supports doctoral training and post-doctoral research and innovation in priority sectors needed to drive economic growth and development across SSA. The RSIF priority thematic areas are: (1) ICTs including big data and artificial intelligence; (2) food security and agribusiness; (3) climate change; (4) energy including renewables; and (5) minerals, mining and materials engineering. *icipe* was competitively selected in 2018 to serve as the Regional Coordination Unit (RCU) for RSIF, with mandate to implement the initiative on behalf of PASET.

The RSIF Programme is guided by an initial six-year strategy (1st July 2018 to 30th June 2024) which is financed from several sources: A World Bank International Development Association (IDA) grant, support from the Government of Korea through a World Bank Trust Fund and membership contributions from sub-Saharan African (SSA) countries, through PASET[2]. As of March 2020, the RSIF contributing countries are Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Rwanda, and Senegal. All countries are encouraged to participate in RSIF activities.

1. Overview of activities

RSIF activities are implemented through three windows, with funding channeled through two funding instruments. The three windows are:

- **Window 1** provides scholarships for PhD training and capacity building activities to strengthen the quality of doctoral education, research and innovation at competitively selected SSA universities (the African Host Universities- AHUs). The scholarships finance 3 to 4-year PhD training programmes for citizens of SSA countries at AHUs. Scholarships include 'sandwich' training that allow students to undertake part of their PhD programme at selected international partner institutions or private companies. Scholars are chosen competitively with priority given to promising young African faculty without PhDs, and women.
- **Window 2** provides research grants that are awarded competitively to faculty engaged in RSIF programs in AHUs and to RSIF graduates who obtain a post-doctoral or permanent position in an academic institution or research centre in SSA.
- **Window 3** provides innovation grants awarded competitively to AHU faculty who submit joint innovation project proposals with private companies. Innovation grants enable faculty and researchers to collaborate with industry and translate outputs of their research into practical uses either through existing companies or by starting up new enterprises.

RSIF's funding instruments comprise a Permanent Fund, which is expected to grow to at least US$15 million by 2024 with proceeds channeled into a General Fund. The General Fund is

[1] PASET was launched by Senegal, Côte d'Ivoire and Ethiopia in 2013 to strengthen Africa's science and technology capability for the socio-economic development of sub-Saharan Africa. Kenya and Rwanda later joined the partnership, followed by Burkina Faso and Ghana. Championing a regional approach which complements individual country efforts, PASET functions as a convening platform by bringing together African governments, the private sector, and new partners, such as Brazil, China, India, and Korea, to invest in Africa.

[2] Individual country governments may join the PASET initiative by contributing US$2 million each.

expected to grow to US$50 million by 2024 and will support the three main windows of the program. Once established, a fund manager will be recruited to manage the Permanent Fund. Contributors to RSIF may contribute to the General Fund (restricted funding) or the Permanent Fund (unrestricted support) or to both.

2. Goal and Broader Objectives

Africa's science, technology and innovation are hampered by weak research and innovation capacity, both human and infrastructure, inadequate funding, and a relatively weak higher education system that is exacerbated by high teaching loads. RSIF aims to support contributing countries to make use of science to respond to key development challenges, by training qualified PhD level graduates to undertake high quality research and training in Applied Science Engineering and Technology (ASET) fields that will lead to transformative technologies, and subsequently increased incomes, reduced poverty and development. PhD scholarships are intentionally awarded to enhance qualified staffing at SSA universities and research institutions in member countries. AHUs are selected and facilitated to ensure the quality of future PhD training, research, and innovation processes. RSIF is also designed to increase the long-term sustainability of research funding for ASET, and to enable countries to build functional innovation ecosystems for sustainable economic growth and development.

During the 2021-2025 period, the RSIF programme will pursue two main objectives:

- **Objective 1**: To build capacity for development for the operation and management of scholarship, research and innovation grants. This component will focus on capacity building for managing and growing the RSIF General Fund and the establishment and growth of the RSIF Permanent Fund. It will also build capacity at *icipe,* RSIF's RCU, for the operation and management of doctoral training scholarships in selected African universities and for designing and managing research and innovation grants. At the AHUs, capacity building will focus on improving the quality of PhD programs including research in ASET fields, guided by a capacity building strategy.
- **Objective 2**: To implement doctoral scholarships, and research and innovation grants through selected AHUs in the five PASET priority areas.

3. Strategic Outlook (2021 to 2025)

RSIF aims to identify and support emerging centres of leadership in research, i.e., specific PhD programmes and departments within AHUs, in the five PASET priority areas to respond to key skills/research and innovation gaps. The Covid-19 pandemic has highlighted the importance of strengthening Africa's core capabilities in science, engineering and technology generation. The pandemic has also revealed opportunities and new insights for making use of technologies that can enhance learning by users.

Building on its long experience in post-graduate training in Africa, *icipe*, through the RSIF, will transfer its scientific capability and experience in capacity building for SSA by supporting the strengthening of postgraduate education at AHUs. Priorities will include: (i) doctoral level training, especially for women and university faculty without PhDs, and (ii) the building of research, innovation and capacity building partnerships with the best universities and research institutions world-wide, and (iii) building partnerships with African governments for increasing Africa's own investments in science and ownership. Additionally, strengthening the knowledge and capacity for use of Intellectual Property (IP) tools and IP Rights will be important for enhancing research-based innovation, which is an area where *icipe* has a track record and relevant experience.

The capacity building of universities to support their adaptation to the current context, which is being driven by COVID-19, will include support to significantly enhance online learning at African universities. This will enable universities to provide remote mentorship, supervision and learning. Universities will be supported to systematically harness more open educational resources (OERs) and related tools. The need for this is highlighted by the current and future

limitation for in-country and cross border travel that could significantly delay students arrival at universities. *icipe* will also provide specific capacity building to RSIF PhD scholars to ensure that they are prepared for the PhD experience, are supported to implement their research, and are adequately prepared for post-doctoral opportunities. This support to PhD Scholars extends *icipe*'s experience and capability.

This expanded commitment to capacity building in Africa provides *icipe* with a pathway to deliver two direct outcomes: 1) Africa benefits from the pool of new scientists making new African-owned discoveries, and African institutions (including universities, research institutions and the private sector) benefit by having access to a better trained and experienced scientists to take up teaching, research or business roles; 2) Together, these direct benefits are multiplied through the next generation of students graduating from an even greater number of universities across Africa. RSIF is positioning itself as the first Pan-African regional science fund with a unique architecture designed for regional impact, multiple partners, flexibility of contributions ensuring common grant allocation rules and professional implementation through *icipe*. The resource mobilization strategy that is currently under development, will be critical for ensuring the long-term success of the RSIF Fund by bringing on board key players to drive its growth.

icipe will use the RSIF initiative as an entry point to multiple selected countries across Africa, especially in West Africa. Collaborative partnerships will be established with key universities or other institutions within these selected countries, and it is these partnerships that will form the foundation for *icipe*'s expansion into these sub-regions. The engagement of SSA Governments will strengthen the quality of these partnerships. The lessons learnt from *icipe*'s previous expansion beyond Kenya has shown that the depth and strength of the institute-to-institute partnerships supported by national and sub-regional agencies are the key to success in scaling-up and -out across national borders.

4. Specific future thrusts

RSIF will contribute to build SSA`s capacity to enhance its scientific and technologically skilled workforce in ASET fields, catalyzing socio-economic transformation in SSA. During the next period, key thrusts will include:

1. **Establishment and growth of the Fund**: RSIF will complement the efforts of national research funds to build research and innovation capacity, creating a fertile environment for innovations and transformative technologies.
2. **Strengthening use of IP for innovation:** The work with international partners and project consortia, including private sector players, calls for the rationalization of IP policies and agreements to ensure that jointly implemented research is available to support the use of knowledge for responding to African development needs.
3. **Engagement of the private sector**: RSIF will focus on strengthening partnerships with the private sector and to ensure that more RSIF scholars are responding to the needs of the private sector and undertaking their research internships within these institutions.
4. **Supporting returning graduates to their home institutions**: As the first set of graduates approach the end of their doctoral studies, the implementation of specific research grants for returning graduates will be undertaken. The first generation of RSIF graduates are largely expected to strengthen faculty capacity in universities and help teach the next generation of scientists, including broadening the pool of women scientists.
5. **Enhancing participation across the continent**: It is expected that other SSA countries will be joining the initiative and number of RSIF African Host Universities and international partner institutions will continue to grow. Through RSIF, *icipe* will build its network of partnerships and impact – and be able to scale up and scale out across the continent through collaborative partnerships with key universities or other institutions in West, Central and Southern Africa[3].

[3] See list of 11 RSIF AHUs and 12 RSIF IPIs as of June 2020. https://www.rsif-paset.org/

Partnership for skills in Applied Sciences, Engineering and Technology (PASET) Regional Scholarship and Innovation Fund (RSIF) Results Based Management (RBM) Rolling Framework

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
Overall Objective: To strengthen the institutional capacity for quality and sustainable doctoral training, research and innovation in transformative technologies in Sub-Saharan Africa (SSA) by 2025					
Specific Objective 1: To develop the capacity for growth and management of a scholarship, research and innovation fund					
Set up a foundation for establishment of an Endowment Fund with contributions from SSA governments, private sector, donors.	Growth in the Regional Scholarship and Innovation Fund for sustained financing of scientific and technical talent development in Africa.	• Foundation for permanent fund established and RSIF growing over time	Legal documents and other relevant governance documents and investment policy documents. Annual financial statements. TORs and meeting notes of Advisory Committee.	*icipe* Regional Coordination Unit (RCU) collects necessary legal and operational documents from those who will register the fund RCU retrieves the annual financial statement of the general fund and permanent fund from the bank account and compile as a report	• African governments and private sector are committed to making priority investments in PhD training and research development and able to overcome economic challenges due to Covid-19 and invest in RSIF. • The World Bank provides implementation support, where necessary • Permanent Fund manager to guard against poor investment performance
Capacity for operation and management of doctoral training scholarships and research grants built	Increased capacity to operate and manage doctoral training scholarships and research grants	• Number of scholarships and grants successfully administered	PhD scholarship and research grants operational manual, presence of necessary staff, functional office and availability of bank account for grant disbursement Grant reports	RCU collects all data described in the data source and compile it as a report Grantees report to RCU	• The doctoral training and scholarship program is built on the experience from similar programs at RCU and other programs
Increased capacity of RSIF African Host Universities for improved quality of doctoral programs and research in ASET	Quality of doctoral programs and research in ASET enhanced at RSIF African Host Universities	• At least 10 agreements signed with RSIF African Host Universities by 2023 • At least 10 RSIF African Host Universities with an online	Signed agreements between RSIF African Host Universities and regional coordination unit Online application system	RCU compiles all signed agreements with RSIF African Host Universities and compiles a report RCU receives the report generated from online application	• RSIF African Host Universities are willing and ready to adopt RSIF changes and policies recommended for improving doctoral training

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
		application system in place by 2023 • At least 8 RSIF African Host Universities that start international accreditation process for the PhD programmes by 2023 • 10 cross-cutting training courses/workshops held for RSIF scholars and researchers by 2023 • 10 implemented networks between RSIF African Host Universities and RSIF international partners for PhD training and research collaboration.	Contracts signed with the accreditation agency and self-evaluation report of the RSIF African Host University Course or workshop catalogue and syllabus Signed agreements with partners	system for each RSIF African Host University RCU asks RSIF African Host Universities to report on the status of the international accreditation process and submit supporting documents RCU compiles all available courses and workshops into a report RSIF African Host Universities report to the RCU with signed agreements RCU will compile the journal or database subscription confirmation in a report	
Capacity for the operation and management of innovation grants built	Improved research and innovation capacity in ASET including transformative technologies in SSA Increase in productivity More industry university partnerships More patents filed More enterprises developed	• Number of Innovation grants successfully managed • 10 firms co-finance innovations grants by 2023 • 6 innovations grants awarded to RSIF African Host Universities / eligible institutions by 2023 • 5 innovation grants awarded to faculty at RSIF African Host Universities by 2023 • 12 innovation grants awarded under AGriDI in West Africa. • 11 RSIF/MozSkills innovation grants awarded.	Operational manual for innovation grant administration, staff for innovation grant, adequately equipped office for innovations grants administrator, available bank account for disbursing innovation grant Signed agreements on co-financing by the private sector	RCU collects all information in the data source and compile a report RSIF African Host Universities report to the RCU with signed agreements	• RSIF African Host Universities are willing to participate in the innovation grant scheme • Private sector partners are willing to collaborate and co-finance innovative projects with RSIF African Host Universities • Innovation projects are successfully transitioned into established enterprises

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
	More employment opportunities created		Financial statement that shows the disbursement of innovation grant to beneficiaries s and the recipients' documented acknowledgement. Grant reports	RSIF Innovations Grants Administration Unit collects the necessary documentation including financial statements, acknowledgement from recipients and other supporting documents and compile the data as a report	
Specific Objectives 2: To establish scholarships, research and innovation grants for ASET by 2025					
RSIF PhD Scholars enrol in selected PhD programs at RSIF African Host Universities	Increased number of PhD scholars with full scholarships enrolling in selected PhD programs at RSIF African Host Universities	• At least 200 (60 female and 140 male) RSIF scholars enrol in selected PhD programs at RSIF African Host Universities	Registration documents from RSIF African Host Universities	RCU collects data from RSIF African Host Universities	• Scholarship calls receive sufficient high-quality applications from women and men
RSIF scholars graduate from PhD programs	Increased number of scientists (at least 32% women) at doctoral level in ASET fields	• At least 157 (46 female and 111 male) RSIF scholars graduate from PhD programs by 2025 • At least 80% of RSIF scolars are satisfied with the quality of the learning environment and delivery of the target doctoral program at AHUs • At least 70% of RSIF graduates are self-employed at least 6 months after graduation	RSIF African Host Universities who track the progress of scholars RSIF Scholar reports Student satisfaction surveys. Graduate tracer studies.	RCU collects data from RSIF African Host Universities and Scholars through reports, student satisfaction surveys and graduate tracer studies.	• Selected RSIF African Host Universities have the enough staff to effectively supervise PhD scholars and teach • Covid-19 does not affect completion time for PhD scholars • Selected PhD grantees are committed to completing the PhD programs • RSIF African Host Universities are willing to implement strategies to attract and retain more women doctoral scholars and researchers • RSIF graduates are relevant for the world of employment with majority of first generation

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
					graduates expected to return to African universities.
Increase in quality of research publications on ASET in Africa	Quality of doctoral programs and research in ASET including transformative technologies enhanced at RSIF African Host Universities	• At least 20,000 scientific and technological journals can be accessed by RSIF scholars and RSIF African Host University researchers by 2023 • At least 35 research papers submitted by staff members or scholars supported by the project for publication to internationally indexed journals by 2023 (of which at least 10 by female authors or co-authors) • At least 10 implemented networks between RSIF African Host Universities and international partners for PhD training and research collaboration by 2025. • At least 120 student/staff that take cross-cutting courses, entrepreneurship and / or research commercialization courses supported by the project by 2023 • At least 16 grants awarded to faculty of RSIF African Host Universities/ eligible institutions by 2023 • 7 RSIF/Mozskills research grants awarded • At least 13 research grants awarded to RSIF scholars by 2023	Journal or database subscription agreements RSIF African Host Universities who track the submission of research papers by RSIF scholars and faculties Financial statement that shows the disbursement of research grant to faculty and the recipients' documented acknowledgement Online course system and trainers Financial statement that shows the disbursement of research grant to scholars and the recipients' acknowledgment	RSIF African Host Universities report to the RCU with supporting documents RSIF Innovations Grants Administration Unit collects the necessary documentation including financial statements, acknowledgement from recipients and other supporting documents and compile the data as a report RCU collects the necessary data from online course system and trainers directly RSIF PhD and research Grants Administration Unit collects the necessary documentation including financial statements, acknowledgement from recipients and other supporting documents and compile the data as a report	• RSIF African Host Universities have the capacity to effectively implement the research grants • Research grant projects use transformative technologies

SOCIO-ECONOMIC AND IMPACT ASSESSMENT UNIT at *icipe*

a. Overview of activities

The Social Sciences and Impact Assessment (SSIA) Unit is a vital component application of biological science for sustainable development. It aims to provide high-quality social science research-based evidence to support and guide *icipe's* technology development and delivery efforts and the overall goal of sustainably reducing poverty, ensuring food security, and improving the overall health status of communities across Africa. The SSIA Unit implements a wide range of activities to support the decision making, policy direction, and priorities of the Centre and various stakeholders, including donors, scientists, and farmers.

The SSIA Unit works closely with the biological researchers across the 4H themes, to undertake joint activities (including resource mobilization), to prioritize, and ensure the relevance and effectiveness of *icipe's* research. It also collaborates with external partners such as international and local research institutes and universities to strengthen its impact evaluations, mobilize resources, build capacity, and execute local activities. In doing so, the Unit will be able to compose multidisciplinary teams and expand the skill sets needed not only to accomplish evaluation but also to ensure quality in the evaluation process.

Across the 4H themes, social science research (SSR) helps assess and document household and societal needs, aspirations, and field realities before new technologies and projects are developed. The Unit will provide leadership in understanding barriers and accelerators to *icipe's* technologies adoption and generating evidence through field research to establish the socioeconomic, environmental, health, and operational feasibility of the promising technologies under field conditions across Africa. It will also involve exploring the impacts of pests and diseases inflicting damage on crops, livestock, human livelihoods, and the environment. Work packages will centre on quantifying the socioeconomic, health, and environmental burden of the alien species and evaluating and extending technical advice on potential mitigation strategies.

The focus of SSIA Unit's work will Centre on fruit flies, Fall Armyworm (*Spodoptera frugiperda*), locust, ticks, trypanosomiasis, and the South American tomato moth (*Tuta absoluta*). Re-emerging health issues related to vector-borne diseases are becoming important public health problems in sub-Saharan Africa (SSA) and will occupy a significant constituent of the SSIA Unit's portfolio of activities. Understanding the socioeconomic burden of parasitic diseases and arboviral diseases among *icipe* target populations will be extended. The SSIA Unit's R4D efforts will be further extended to improve understanding of socioeconomic aspects of arthropods and their role in ecosystems; and their contribution to conservation and sustainable utilization of biodiversity and climate change mitigation and adaptation. Similarly, it is becoming clear that the destruction of biodiversity due to the excessive use of insecticides, loss of habitats, and climate change has resulted in lower yields for several agricultural commodities across the SSA.

SSIA Unit's work will focus on understanding and quantifying the impact of biodiversity loss and support the development of innovative methods of pest control that do not rely on agri-chemicals. Work will entail comparative cost-effectiveness and efficiency studies of non-agri-chemicals based interventions versus the agri-chemical based approaches. The Unit will collaboratively monitor the impact of biodiversity loss on bee production as an alternative source of income, developing R&D interventions that provide pathways for women and youths to build enterprises based on silk farming, and bees and honey products. The rapid increase in population and subsequent demand for feeding livestock and humans requires that more innovative and cost-effective ways of producing feed and food are evaluated. The Unit will provide leadership in assessing the socioeconomic and environmental impacts, cost-effectiveness, and acceptability of insect-based food and feed options found technically feasible with research in the Plant Health

Theme. Cost-effective options of producing insects on a mass scale and establishment of willingness to pay for feed and food, products with insects included, will be explored and promoted under the leadership of SSIA Unit.

The SSIA Unit will continue to broaden its R4D efforts towards improving women and youth livelihoods. It will generate evidence on gender roles and the technologies, which will help to advocate for the systematic integration of gender in research activities, projects and programmes at *icipe*. The Unit will ensure that there is an adequate emphasis on a research agenda focusing on gender, youth, and social equity aspects of *icipe's* science and technologies. In collaboration with the Technology Transfer Unit, the SSIA Unit will facilitate the scaling of *icipe* technologies. Finally, resource mobilization, disseminating evidence-based policy to influence policy decision making, and equipping the young generation with state-of-the-art economic tools are at the heart of the Unit.

b. Goal and Broader Objectives

By 2025, the SSIA Unit will have contributed to the innovations development process and delivery efforts, which aimed at sustainably alleviating poverty, improving food and health security, while sustaining the environment. This will be achieved through: (i) prompting rigorous social science research that supports evidence-based policy development and decision making, and design of institutional innovations that enhance the livelihoods of the African population; (ii) understanding how, where, and for whom the innovations are working for and achieve the most significant impact (technologies targeting); (iii) identifying the constraints to and incentives for faster technology and evidence adoption; (iv) providing evidence and expertise to translate research evidence to policy actions; and (v) developing capacity of partners.

c. Strategic Outlook (2021 to 2025)

The SSIA Unit undertakes solution-focused SSR to address existing and emerging agricultural development problems facing the African population by implementing the following research themes. This strategic outlook involves use of cutting-edge social science methodologies, including randomized controlled trials, pesticide environmental accounting (PEA) tool, participatory qualitative research, observational techniques, and the design and implementation of socioeconomic intervention evaluations.

(1) Gender-responsive Monitoring and Evaluation (M&E), adoption and impact assessment

We do our impact assessment research at three phases: (i) prospective phase of research-to-development (ex-ante analysis) - to enhance priority settings; (ii) implementation phase (M&E) - to keep or adjust the trajectory of activities by providing current perspectives on progress, process, and operational issues; and (iii) retrospective phase (ex-post analyses) - to document impact and draw out lessons. The research activities under this research theme include the following.

1.1. Needs assessments and situational analyses to support technology innovations

This activity will involve the use of robust participatory tools and methods to assess and document household and societal needs, aspirations, and field realities before the development of new technologies and projects. For instance, the Unit will collect and document stakeholders' perceptions and attitudes on new technologies, and this feedback provides essential information for the design of appropriate technologies and the development of viable project proposals. This type of information will enable the Centre to save resources (time, money, and human) by guiding the biological scientists to invest resources only in innovations/technologies that have a high chance of success, based on their acceptability and adaptability to current farming systems. The information will also help *icipe* and partners to organize research agendas, and educational, and training activities around the key insect-related problems faced by farmers and communities.

1.2. Evidence to facilitate adoption and scaling up of technologies

The second activity under this strategic theme will aim to generate knowledge on the key drivers of and barriers to adoption and the most promising approaches to scaling up new technologies. This involves ex-ante and ex-post adoption studies to understand the behaviour of potential adopters of innovations and technologies and identify agricultural information delivery and scaling up of strategies to enhance the transfer of technologies developed by *icipe* to the end-users. The Unit regularly collects gender-disaggregated data to capture the role of gender on adoption and diffusion of innovations. For instance, the Unit is currently generating a gender-disaggregated panel database on adoption and diffusion for Centre flagship technologies (e.g., push-pull technology, biopesticides, and IPM for mango fruit fly) to track adoption over time and examine the sequential and intertemporal adoption behaviours of farmers.

1.3. *Novel tools and methods for ex-ante and ex-post impact analysis*

The third research priority area of this strategic outlook will be the use of novel tools and methods for ex-ante and ex-post impact analysis of *icipe's* (4H-Themes) innovations and technologies, to provide critical information for policymakers and donors, to enable them to make informed policy choices for better targeting of the poor and wider diffusion of innovations. SSIA Unit's research in this area continuously applies improved ways to track impact pathways and causally link adoption directly to specific impacts, such as agricultural productivity, nutrition security, health, and poverty. Quasi-experiments have been the main design used for impact assessment at *icipe*. However, the Unit will further advance the use of experimental approaches (randomized controlled trial, RCT). In assessing the impact of *icipe's* innovations and technologies, the Unit will collect and use disaggregated data to measuring the differential impacts of the technology used on different social groups (women, men, and youth). The Unit also plans to conduct studies (i) to generate evidence on the rates of return to *icipe's* investment in research and demonstrate value for money; and (ii) assess the social and private costs of pesticides and adoption of pesticide-free technologies. Research findings from the impact studies provide information that can assist *icipe* and its biological scientists in developing technologies that are feasible and attractive under field conditions and have a higher likelihood of positively impacting stakeholders. These impact assessments also provide the evidence needed by policymakers and donors for the development of effective policies and programs for scaling technologies that alleviate food insecurity and poverty.

1.4. *Digital M&E and survey platform*

One of the lessons we learned from COVID-19 is that our M&E and data collection system need to be integrated with digital technology for the continuity of project activities. As data capture continuously becomes more and more expensive, the SSIA Unit will increase its use of on-line surveys/data capture and M&E system to reduce the cost of undertaking impact evaluations continuously. Several innovative digital M&E systems, surveys and approaches will be adapted and rolled out.

(2) Policy and strategies design

2.1 Translate research evidence into policy actions for widespread adoption of technologies and greater impact

The priority under this theme is to develop strategies and facilitate policy formulation to increase the adoption of *icipe's* technologies and evidence. The Unit, in collaboration with *icipe* local partners, will:

- Synthesize adoption and impact evidence and provide the necessary expertise for policy development;
- Conduct policy and society dialogue with the policymakers and stakeholders by organizing dedicated policy workshops and consultation meetings; and
- Engage with the general public using effective communicational channels such as regional and national platforms, direct approach, media, and preparing non-technical policy briefs.

2.2. Analysis and evaluation of policies and regulations for input delivery and innovation systems
Activities in this research area will involve analysis and evaluation of policies, incentives, and regulations that govern input delivery and innovation systems for some of the innovations developed by *icipe*, in the various target countries. The SSIA Unit will conduct participatory studies to evaluate and understand the laws and regulations governing input and innovations in the target countries. The Unit will work closely with the BioInnovate Africa and Regional Scholarship and Innovations Program (RSIF) at *icipe*; which support scientists, researchers, and innovators in the region's universities, research institutes, and firms to link research ideas and technologies to businesses and the market. The Unit will leverage case studies designed to understand the process from innovations to market and inform policy on improving the transfer of innovations to end-users.

(3) Institutional innovations, marketing, and value chain analysis
3.1. Understanding the structures and functions of value chains of icipe products
The priority area of this strategic theme will be to provide a better understanding of the structures and functions of markets for selected target products resulting from *icipe* interventions. Examples of products to be considered for market analysis include fruits, vegetables, maize grain, milk, insect-based feeds and foods, honey, and silk. The research will focus on identifying market challenges and opportunities, market channels and actors, the distributions of prices, and measures of margins and transaction costs along the value chains. The analysis will also provide information about the existing output channels, opportunities, benefits, and constraints faced by women, men, and the youth along the value chains. Identifying underutilized value chain opportunities for smallholders will help devise strategies to strengthen the value chain and increase the commercialization of the products.

3.2. Test alternative institutional innovations for improving technology delivery and markets
In the second research area, staff will develop and test alternative institutional innovations and business models for delivering and financing technologies (e.g., Brachiaria and desmodium seeds, repellent tsetse collar, biopesticides, IPM package) and for improving markets for small-scale producers and consumers, with particular emphasis on reducing transaction costs and promoting technologies at a lower cost. The objective will be to determine the combination of players that can ensure the efficient, equitable, and sustainable supply of the technology and agricultural products to the end-users. Under this activity, we will assess: (i) the effectiveness of farmer organizations, input supply companies, government extension agents, farmers-to-farmers extension or social network, and other service providers such as local NGOs in delivering technologies to farmers; (ii) test various technology dissemination strategies in scaling out innovations and evaluate how institutional innovations such as intellectual property rights and incentives may affect the supply of the technologies; and (iii) assess access to contract farming, finance, market information, value addition, product differentiation, certification, storage, and other services that are required for technology adoption and efficient transactions. Such innovations in marketing arrangements can reduce market imperfections and help transform market relations to benefit smallholders.

3.3. Policy options for enhancing the market environment for target products
The third research area will focus on evaluating and developing policy options for enhancing the market environment for the target products, with emphasis on the appropriate role of the public and private sector, and barriers to and competitiveness in regional trade and international trade. The research will include identifying and assessing the impact of policy distortions and promotion of enabling policy options that improve market efficiency, integration of smallholder producers, and diversification of demand for the products considered.

(4) Climate change and environment
4.1. Economic valuation of ecosystem services, and their impact on livelihoods

The first priority area will focus on the economic valuation of ecosystem services and their impact on livelihoods. The research will estimate and compare the value of pollination services provided by managed honeybees and wild bees in the target countries. Pollinators play a significant role in food production, but literature on the value of pollination is scarce in Africa.[4] Estimating the value of pollination service can generate useful information that is needed to compute the costs and benefits of conserving habitats for pollinators in agricultural systems, which is necessary to guide proper land use planning in agrarian economies. The research work in this area will also focus on evaluating the impact of the pollinator abundance and diversity on crop productivity, food security, and income of households.

4.2. Impact of icipe "climate-smart" technologies and practices on environmental health

The second research area will be to understand the impact of ***icipe's*** "climate smart" technologies and practices (such as the push-pull technology, IPM, biopesticides) on environmental health (using the environmental impact quotient, pesticides environmental accounting), and climate change adaptation and resilience among rural households and communities. The research will further explore policy options to promote environmental sustainability and mitigate the adverse effects of climate change in the target countries.

(5) Cross-cutting issues

5.1. *Gender analysis and women's empowerment*

Gender analysis to understand the role of ***icipe's*** intervention in gender equality and equity studies are a major part of the SSIA Unit's research activities. Women play a significant role in agricultural production in Africa, but they lag behind their male counterparts in access to livelihood assets (natural, human, financial, physical, social, and political) necessary to raise agricultural productivity. Understanding gender roles and relations along agricultural value chains is critical for the design of institutional innovations to promote technology adoption. This is crucial for achieving long-lasting, equitable, and bigger impacts of ***icipe's*** science and technologies. Priority research areas under this strategic theme include: (i) valuation of women's empowerment in agriculture and the impact on family livelihoods; and (ii) evaluation of gender-sensitive interventions on women's and men's livelihoods. This research will generate: (i) knowledge and data for better understanding factors that lead to women's (dis-) empowerment; (ii) knowledge and data on women's, men's, and youth's ability to adopt *icipe* innovations and impacts of innovations on livelihoods of these groups of households; and (iii) institutional advise for project implementation to specifically address men, women, and the youth with targeted innovations.

5.2. Capacity development

The SSIA Unit's commitment to capacity strengthening in the areas of social science research and gender mainstreaming will be implemented through joint research and short-term training. The Unit will continue to host and guide MSc and Ph.D. students from partner countries and support thesis research through sharing *icipe* databases and appointment of staff to advisory committees. The SSIA Unit staff will also mentor social scientists in NARES, as well as young scholars from advanced research institutes seeking first-hand, practical research experience. The SSIA Unit, through its work with the Regional Scholarship and Innovation Fund (RSIF) programme, contributes to the advancement of women in Science, Technology, Engineering, and Math (STEM) disciplines in Africa by developing recommendations for how RSIF can increase women's representation among its Ph.D. scholars. The Unit will also ensure internal capacity development by supporting staff to attend relevant short refresher courses, seminars, and conferences.

[4] Globally, about 70 percent of flowering plants require biotic pollination biotic for reproduction, and more than 30% of the world's crops are pollinated by bees.

d. Specific future thrusts (2021 to 2025)

Economy-wide effect of technologies*: icipe* technologies have impacts on multi-sectoral sectors beyond agriculture. Capacity needs to be strengthened to simulate the economy-wide and poverty implications of our technologies at the national level using **general equilibrium and agent-based models.**

Promotion and socioeconomics of One Health approach: Farmers have a combination of challenges (problems related to plant, animal, and human health; resource degradation; and climate change) that hinder their efforts to achieve food security and escape poverty. While this is the case, interventions (projects) are often promoted to address a single problem. The sustainable and optimal impact of our interventions can be achieved through the adoption of a holistic approach. *icipe* has embraced One Health concept. Challenges are many, including donors' and scientists' interest, to promote One Health approach. The Unit will encourage scientists during proposal development to consider One Health approach and assess the impacts of this approach on farmers' livelihoods and the economy.

Impact of *icipe's and donors investment on* capacity building: The unique feature of *icipe* is its capacity building program, where hundreds of students affiliated every year. It is important to evaluate the impact of *icipe*'s large investment in human capital development in Africa.

Agribusiness and markets: Appropriate markets and business models are crucial for transferring and scaling technologies. Efforts need to be strengthened to enhance the marketing and business development skills of the Unit through hiring the needed experts to support large R4D projects.

Social Sciences and Impact Assessment unit RBM Rolling Framework

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
Objective 1: Evaluate the livelihoods, environmental, and health impacts of pests and Integrated Pest and Vector Management strategies (IPVMS)					
1. Quantify the socioeconomic health and environmental impacts of invasive pests and diseases	Stakeholders aware of the economic burden of pests and make an informed decision on the control and management of pests	Papers documenting evidence on the economic burden of pests in Africa	Farmers, key informants, agricultural experts	FGD and household surveys	Farmers are willing to participate in the interview and provide information
1. Socioeconomic, environmental, nutrition, and human health impacts of IPVMS and pesticides use at micro-level established	Policymakers and development partners aware potential demand of IPVMs and use better evidence in decision making to scale up IPVMs to control pests	Manuscripts on socioeconomic, health, and environmental impacts of IPVMS	Farmers, key informants, agricultural experts	FGD and household surveys, RCT	Farmers are willing to participate in the interview and provide information
2. Stakeholders IPVMS adoption behavior and constraints to and opportunities for faster adoption of IPVMs documented	Policymakers and development partners aware potential demand of IPVMs and use better evidence in decision making to scale up IPVMs to control pests	Manuscripts on the adoption behaviour, intention to adopt , and constraints and accelerators of IPVMS.	Farmers, key informants, agricultural experts, agro-dealers, researchers, policymakers	FGD and household surveys, RCT	Farmers are willing to participate in the interview and provide information
3. The role of social learning, incentives, nudging, and training on the adoption of IPVMS and health-seeking behavior determined and documented	Policymakers and development agents have improved understanding and knowledge of social learning as a strategy for stimulating technology adoption	Working papers on the effect of social learning, incentives, nudging, and training on knowledge diffusion, adoption of IPVMS, and households' health-seeking behavior	Farmers, key informants, agricultural experts	Household surveys, RCT	Farmers are willing to participate in the interview and provide information
4. Cost-effectiveness and cost-benefit analysis of the IPVMS	Actors along value chain chains made aware of the potential demand of the integrated tsetse and ticks management practices	Working papers	Farmers, key informants, agricultural experts	Households surveys, RCT, FGDs, Key informants' interviews	• The political situation is favorable. • Market value chain actors agree to be interviewed • Availability of funds.

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
5. Economy-wide impacts of IPVMS and pesticides use	*icipe's* interventions benefits to different economic sectors in Africa is recognized	• Working papers on employment, poverty, and GDPs of countries of *icipe's* interventions • Working paper on social costs of pesticides	Farmers, key informants, literature reviews agricultural experts,	Surveys, literature reviews, FGDs	
6. Characterizing stakeholders' awareness and knowledge of pests and diseases and control measures	Data and stakeholders' behavior on knowledge, attitudes and practices to adapt IPVMS and enhance their adoption	• Working papers on stakeholders' behavior of pests and diseases management	Framers, literature	Surveys, FGDs	
Objective 2: **Socioeconomics and environmental implications of edible insects**					
1. Environmental, economic, food security, employment, and climate change mitigation benefits of edible insects farming for feed and food	Policymakers, the scientific community, and development are aware of the potential value of insect-based feed	• Papers on socioeconomic-environmental-health-climate mitigation benefits of insect farming and insect-based feed	Framers, FGDs, literature review	Surveys, FGDs, experiments	
2. Consumers and producers intention to farm and consume edible insects	Understood drivers and barriers of edible insects scaling up	Papers	Framers, FGDs, literature review	Surveys, FGDs	
Objective 3. Role of digital agricultural technology in scaling up technologies and livelihoods and M&E systems					
1. Understand gender roles, barriers, and enablers to decision-making and other household dynamics influencing Digital Agricultural services (DAS) adoption	Key insights gained on the role of gender and youth in the adoption of sustainable agriculture via DAS. Insights gained on triggers of behavior change through information at household-level	A working paper on the role of gender and youth in the adoption of sustainable agriculture (SA)	Farmers, key informants	Surveys, FGDs	
2. Role of DAS on sustainable agricultural practices (SAPs) adoption and well-being	Role of DAS on long-term behavioral change within households assessed	A working paper on role of DAS behavioral change A working on DAS impact on SA practice adoption	Farmers, key informants	Surveys, FGDs	

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
	Effect of DAS on scaling of sustainable agriculture and well-being across communities assessed Research results synthesized, and key results published				
3. Cost-effectiveness of DAS	Relatively benefits of DAS to conventional extension systems established	Papers	MoA, farmers, literature review	Documents, survey, publications	
3. Web-based M&E system established	One-stop data shopping system in place	Weblink	Framers, youth, experts, partners	Surveys	
4. Continuous monitoring and evaluation oversight functions and capacity building for the project	Projects/programs progress are on track	Number of projects monitored and evaluated	Routine project report	Review of project report	Willingness of project stakeholders to participate in the survey
Objective 4. Gender and youth mainstreaming and research analysis					
1. Women's empowerment index analysis	Policymakers and development partners are aware of Women's Empowerment in Agriculture	Working papers on Women's empowerment indicators	Women and men farmers	Gender surveys, FGDs	Farmers are willing to provide information, enabling the environment
2. Women's empowerment roles on food and nutrion security, adoption, and enhancing the performance of technology	Evidence on women's empowerment on development generated	Working papers	Men and women farmers	Gender surveys, FGD	
3. Assess the gender differential adoption and impact of IPVMS and invasive species	Policymakers and development partners have enhanced knowledge on the gender-based technology adoption differentiated impacts of malaria burden in rural households	Papers on gender-based adoption and impacts of IPVMS and invasive species	Farmers, scientists, researchers,	Surveys, FGDs	Farmers are willing to participate in the interview and provide information
Objective 5. Ecosystem services and commercial insects roles in food systems					

Outputs	Outcome	Performance Indicators	Data Source	Means of obtaining data	Risks and assumptions
1. Role of pollination services and disrupting cropping pattern in closing nutrition gaps in sub-Saharan Africa	Evidence on value of pollination services determined, contributing to pollinators and pollinator habitats management	Working papers	Framers, literature review	World Bank-LSMS data	
2. Commerical insects economy-wide impact assessment	Evidence on the role of commercial insects such as beekeeping role on country's poverty reduction, employment, and GDPs contribution	Working paper	Framers, youth Literature review	Surveys, existing related studies	
3. Beekeeping impacts at micro-level	Beekeeping technology adoption impacts on relaxing income and liquidity constraints demonstrated	Publications	Framers, youth, literature review	Surveys, existing related studies	
4. Integration of IPM and pollination services effect at the micro-level	One health concept demonstrated	Working papers	Framers, youth, literature review	Surveys, experiments, existing related studies	
Objective 6. Market and value chain analysis					
1. Business models to connect smallholders to markets and promoting *icipe* technologies	Viable business models identified	Papers	Actors along the value chain	Surveys, FGDs	
2. Gender-based value chain analysis of *icipe's* related commodities	Barriers and opportunities to market participants and potential solutions identified	Papers	Actors along the value chain	Surveys, FGDs	
3. Role of markets on *icipe's* technology adoption		Papers	Actors along the value chain	Surveys, FGDs	
Objective 7. Capacity building impact assessments					
1. Evaluate *icipe's* and its partners capacity-building investment	Value of capacity investment quantified	Working paper	*icipe's* alumni, employers, students	key informant survey, secondary data	Getting alumni contact
2. Mentor Ph.D. and MSc students	Students graduated	Number of graduated students	Unit record		

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