2019 *icipe* CORE ANNUAL REPORT

PROGRAMMATIC REPORTING BASED ON RESULTS BASED MANAGEMENT (RBM) WITH THE AID OF THE LOGICAL FRAMEWORK APPROACH (LFA)

May 2020

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Cover page: *Cotesia typhae* (Hymenoptera: Braconidae): A parasitoid which is specific to a stem borer, *Sesamia nonagrioides*, living in wild habitat in Kenya, and it is an important pest of maize in France.

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List of Acronyms

AAIS	African Association of Insect Scientists
AAT	African Animal Trypanosomiasis
AAU	African Association of Universities
ACIAR	Australian Centre for International Agricultural Research
AGM	African Green Monkey
AHU	African Host Universities
AIRCA	Association of International Research and Development Centres for Agriculture
Anti-VEC	Application of Novel Transgenic technology & Inherited symbionts to Vector Control
ARPPIS	African Regional Postgraduate Programme in Insect Science
BFT	Bean Flower Thrips
BSF	Black Soldier Fly
BSFL	Black Soldier Fly Larvae
BUK	Bayero University Kano
CBID	Capacity Building and Institutional Development
CICB	Crop Inspection and Certification Board, Uganda
CIM	Centre for International Migration and Development, Germany
CORPs	Community Owned Resource Persons
DFID	Department for International Development, UK
DNA	Deoxyribonucleic acid
DRIP	Dissertation Research Internship Programme
DRSS	Department of Research and Specialist Services, Zimbabwe
EANBiT	Eastern Africa Network of Bioinformatics Training
EU	European Union
FAMEWS	Fall armyworm Monitoring and Early Warning System
FAO	Food and Agriculture Organization of the United Nations
FAW	Fall armyworm
FLAIR	Future Leaders – African Independent Research
fPOM	Free Particulate Organic Matter
GA	Glutamic acid
GC-MS	Gas Chromatography-Mass Spectrometry
GCRF	Global Challenges Research Fund
GDP	Gross Domestic Product
GPFS	Global Programme for Food Security
GSH	Glutathione
HBH	Honeybee Honey
HRM	High-Resolution Melting
ICBP	Innovation Capacity Building Programme
icipe	International Centre of Insect Physiology and Ecology
IJT	International Journal of Tropical Insect Science
INSEFF	Insects for Food and Feed
IPM	Integrated Pest Management
IPPM	Integrated Pest and Pollinators Management
IRC	Information Resources Centre
ISVM	Integrated Surra and its Vector Management
KEPHIS	Kenya Plant Health Inspectorate Services
KIST	Korean Institute of Science and Technology
KLISC	Kenya Libraries and Information Services Consortium

LC-MS	Liquid Chromatography-Mass Spectrometry
LIMS	Laboratory Information Management System
M&E	Monitoring and Evaluation
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MCF	Mastercard Foundation
MOU	Memorandum of Understanding
MOYESH	More Opportunities for Young Entrepreneurs in Silk and Honey
NARES	National Agricultural Research and Extension Systems
NBCC	National Biological Control Programme
NDVI	Normalized Difference Vegetation Index
NHP	Non-Human Primates
NM-AIST	Nelson Mandela African Institution of Science and Technology
Norad	Norwegian Agency for Development Cooperation
NRS	Nationally Recruited Staff
NSRC-Kenya	National Sericulture Research Centre, Kenya
OECD	Organisation for Economic Co-operation and Development
PASET	Partnership for Skills in Applied Sciences, Engineering and Technology
PS	Pollination Services
R&D	Research and Development
R4D	Research for Development
RCT	Randomized Controlled Trial
RCU	Regional Coordination Unit
REDCap	Research Electronic Data Capture
RSIF-PASET	Africa Regional Scholarship and Innovation Fund for Partnership for Skills in Applied Sciences, Engineering and Technology
SAR	Synthetic Aperture Radar
SBH	Stingless Bee Honey
SDC	Swiss Agency for Development and Cooperation
Sida	Swedish International Development Cooperation Agency
SIV	Simian Immunodeficiency Virus
SOC	Soil organic carbon
SON	Soil organic nitrogen
SSA	sub-Saharan Africa
STC-EST 3	3rd Specialized Technical Committee on Education, Science and Technology
SUA	Sokoine University of Agriculture
U-FHB	University Félix Houphouet-Boigny
UG	University of Ghana
UGB	University of Gaston Berger
UM6P	University Mohamed 6 Polytechnic
VMD	Kenya Veterinary Medicines Directorate
WASH	Water, Sanitation and Hygiene
WPI	Worcester Polytechnic Institute
YESH	Young Entrepreneurs in Silk and Honey
YF	Yellow Fever

EXECUTIVE SUMMARY

icipe 2019 Results Based Management Report

This report highlights significant progress made by the Centre during January – December 2019, across all its activities with interlinked advances in basic science; development and dissemination of technologies and strategies to control crop pests and disease vectors; as well as contributions to various national policies. These efforts were supported by socio-economic knowledge, remarkable expansion of the Centre's capacity building portfolio, resource mobilisation and enhanced communication efforts.

While details are presented in the logframe tables for each core activity area framework, highlights include fundamental knowledge to improve the push-pull technology; information on citrus diseases and proposals on their management; encouraging progress on management of the fall armyworm; and use of pheromone blends and biopesticides to control a range of pests. Further, the Centre intensified research in neglected tropical diseases, and emerging diseases, and formed partnerships, especially with public health institutions, for their effective control. *icipe* also contributed to globally outstanding research on malaria. Meanwhile, the Centre heightened the upscaling and development of innovative, affordable, and community specific tools to manage vectors and diseases of livestock. Commercial enterprises on beneficial insects, grounded in scientific and technological knowledge, remained a central and effective area of *icipe* focus. And through studies on improved insect rearing, development of business models, policy recommendations, and training and awareness creation efforts, *icipe* has created a buzz for insects for food and feed and other uses as an exciting opportunity across the region.

In regard to capacity building, *icipe*'s longstanding programmes trained postgraduate scholars; postdoctoral fellows; and research interns. The Centre also led efforts in strengthening bioinformatics for biosciences research, and in boosting ability of researchers, farmers, national programme partners among others, to adapt knowledge intensive *icipe* technologies and products. The Partnership for Skills in Applied Sciences, Engineering and Technology - Regional Scholarship Innovation Fund (www.paset-rsif) has been a game changer that is allowing *icipe* to contribute to high quality doctoral training, research, and innovation in Africa, in identified priority areas of economic growth.

The contribution of *icipe* to Africa's socio-economic transformation is further demonstrated through the successful management of BioInnovate Africa Programme, one of Africa's largest regional innovation-driven initiative, now funding 20 bioscience enterprises.

icipe's solid standing within the scientific community is evident, with 143 peer reviewed journal articles and 151 other scientific publications that were published during this period. Commensurate to the research and development achievements, the Centre earned over 2,500 media mentions in local and international media in 69 countries, and over 4 million mentions on social media. Most of this coverage is available online with many of the items reproduced, on average, by five additional outlets (beyond the initial publisher or broadcaster).

The year 2020, is a significant exciting time as the Centre celebrates its silver jubilee. This significant milestone is embodied in the slogan 'Insects for Life' – a dual expression of the interlinkage between Human, Animal, Plant and Environment Health, and the unwavering commitment of the Centre to its vision and mission. While a range of activities are planned to run all throughout the Jubilee year, the key, and very high-profile event was re-scheduled from 3 April 2020 to 20 November 2020 owing to the coronavirus disease 2019 (COVID-19) global pandemic. A centrepiece of the occasion during the anniversary celebration later in the year will be the launch of the *icipe* Vision and Strategy, 2021 – 2025, and a special Report highlighting *icipe*'s achievements over the last 50 years.

SECTION 1: INTRODUCTION

icipe Centre-wide Themes/Programmes and brief on its Results Based Management (RBM) Framework

Established in 1970, *icipe* (www.icipe.org) is a Centre of Excellence for research, development and capacity building in insect science and its application and the Centre works on:

Plant Health Theme: Contribute to stabilising horticultural and staple food production by reducing quantitative and qualitative pre- and post-harvest yield losses due to insect pests, mites, weeds and mycotoxin-producing fungi by developing economically viable and ecologically sound production systems with low pesticide input.

Animal Health Theme: Contribute to the improvement of livestock health and productivity through the development of integrated strategies and tools for livestock disease vectors' control and adoption by development partners, thus leading to greater availability of meat and milk, hides and draught power and thereby assisting livestock owners to get out of the poverty trap.

Human Health Theme: Contribute to the reduction of malaria and other vector-borne diseases by developing tools and strategies that control the vectors and break the cycle of transmission and integrate these with efforts to manage other diseases.

Environmental Health Theme: Conservation and sustainable utilisation of the agricultural production base and important natural ecosystems, by encouraging and utilising arthropod diversity, cataloguing and sharing biodiversity data, and discovering endemic wealth by bioprospecting for useful natural products.

Capacity Building and Institutional Development (CBID) Programme: Develop well-trained and highly motivated human capacity and strengthen institutional and policy making capacity and capability required to respond to the arthropod-related development challenges in Africa.

BioInnovate Africa Programme: BioInnovate Africa supported by the Swedish International Development Cooperation Agency (Sida) is a programme that supports scientists and innovators in the region to link biological based research ideas and technologies to business and the market. Current BioInnovate Africa partner countries are Burundi, Ethiopia, Kenya, Rwanda, Tanzania and Uganda.

The Partnership for skills in Applied Sciences, Engineering and Technology (PASET) - Regional Scholarship and Innovation Fund (RSIF) Programme: The RSIF is an Africa-led flagship initiative of PASET. 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 is supporting 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 information, communication and technologies (ICTs) including big data and artificial intelligence; food security and agribusiness; climate change; energy including renewables; and minerals, mining and materials engineering.

The *icipe*'s journey towards Results Based Management (RBM) with the aid of the Logical Framework Approach (LFA)[1] started in early 2010, when *icipe*'s Governing Council (GC) and Management, in consultation with its core donors, agreed to develop an RBM framework to support the Centre's Strategic Priorities, Policies and Guidelines for research and development (R&D) of insect science. Since 2012, *icipe* instituted the RBM as an operational framework that explicitly links the strategic objectives and priorities of the Centre to the various themes, programmes and projects that it finances through its donor support and that collectively contribute towards achieving its goals and objectives. Each of *icipe's* core activity area has a specific RBM framework. All project-based activities go through a cycle of knowledge management and continuous learning. The RBM-LFA is indeed a strategic management approach that ensures *icipe*'s R&D activities are implemented in collaboration with our partners to contribute to a logical chain of results that provide knowledge-based solutions aimed at equipping the communities in Africa to sustain livelihoods within a rapidly changing global environment.

[1]Ortengren, K. 2016. A guide to Results-Based Management (RBM), efficient project planning with the aid of the Logical Framework Approach (LFA). Swedish International Development Cooperation Agency (Sida), Stockholm, Sweden, 42p. https://www.sida.se/contentassets/9d257b83f4124113a324c61715150722/21920.pdf

SECTION 2. ADVANCES IN RESEARCH AND DEVELOPMENT (R&D) OUTPUTS AND OUTCOMES

icipe continues to be a thriving hub for advances in basic and applied research in tandem with steady progress in dissemination and uptake of its products and technologies. Highlights of major advances in R&D during 2019 are provided below.

2.1 PLANT HEALTH THEME

Push-pull programme

2.1.1 Desmodium root extracts suppress aflatoxin and fumonisin producing fungi in push-pull farming system

- Crude *Desmodium intortum* and *D. uncinatum* root extracts significantly reduced radial growth of *Aspergillus flavus* and *F. verticillioides* isolates by approximately 60% and 20%, respectively. Through reduction of fungal inocula in the soil, the populations of the fungi infecting maize during growth are reduced and consequently the levels of aflatoxin and fumonisin in maize at harvest time.
- This is another mechanism by which push-pull cropping system reduces the occurrence of maize ear rots and ear rot fungi in addition to the effective control of stemborers and Fall armyworm.
- Although additional studies are underway, the observed activity of the extract could be attributed to presence of bioactive chemicals such as flavonoids and alkaloids, that inhibit spore germination, alter hyphal modifications.

2.1.2 Push–pull technology for improving soil health in western Kenya

- Push-pull cropping systems improved soil health by increasing soil organic carbon (SOC) and soil organic nitrogen (SON) contents while also enhancing plant available phosphorus (P) level. After 12-17 years of push-pull management with realized economic benefits to smallholders, the average values of SOC and SON in push-pull plots were 15.0 and 1.18 g kg^{-1} compared to non-push-pull soils with values of 12.8 and 0.87 g kg^{-1}, respectively. The presence of nitrogen (N) fixing legume, desmodium in the push-pull plots contributed to the striking three-fold increase in free particulate organic matter (fPOM) N in push-pull compared to non-push-pull soils.
- Because of the observed quantitative and qualitative differences in labile organic matter fractions in soil, we expect that push-pull soils have a greater capacity to supply crops with both N and P compared to non-push-pull soils.

2.1.3 Fruit fly parasitoid releases

- During the reporting period, two highly efficient exotic fruit fly parasitoids (*Fopius arisanus* and *Diachasmimorpha longicaudata*), were released for the first time in Arba Minch, Ethiopia, a major mango growing area to control the invasive *Bactrocera dorsalis*. This is a major milestone given the previous difficulties in introduction of exotic organisms into the country. Impact data are being collected.
- Colonies of *F. arisanus* and *D. longicaudata*, have been shipped to Zimbabwe and laboratory culture of the two parasitoids have been established in Zimbabwe's Department of Research and Specialist Services (DRSS) for field releases.

Fruit Fly IPM programme

2.1.4 Fruit fly chemical ecology

- The previously identified host marking pheromones, glutathione (GSH) and glutamic acid (GA) as oviposition deterrents against the indigenous mango fruit fly species *Ceratitis cosyra*, and *C. rosa*, respectively, have been evaluated under field condition for two successive mango seasons at two different locations.
- The results showed that GA reduced the populations of *C. rosa* and *C. fasciventris* by up to 70-80%, while GSH reduced the population of all *Ceratitis* species tested by up to 90%. These identified host marking pheromones offer a potentially effective and environmentally friendly option that can be integrated into the management toolbox of fruit flies.

Tuta IPM programme

2.1.5 Sustainable management of Tuta absoluta, an invasive pest of Solanaceous vegetables

- A baseline survey was conducted to assess the farmers' perceptions of the impacts of and management of tomato and other Solanaceous vegetable pests and the economic burden of *T. absoluta* in tomato production. Results confirmed that *T. absoluta* is the major tomato infesting pest and that the main control method has been through indiscriminate use of synthetic insecticides in Kenya, Tanzania and Uganda.
- Results also showed that growers are aware of the negative impact of these insecticides and expressed positive willingness to pay for alternative methods for management of *T. absoluta*.
- A total of 132 NARES staff and 1,034 farmers were trained on management of the pest during the period under review.
- The pre-release assessment of the efficiency and host specificity of the introduced parasitoid *Dolichogenidea gelechiidivoris* has been concluded. Results showed that the parasitoid is highly specific to *Tuta absoluta*, with parasitism of over 70%. Based on these findings, *icipe* has been granted a permit by Kenya Plant Health Inspectorate Services (KEPHIS) to release the parasitoid in selected sites. This will be the first classical biological control programme for *T. absoluta* since its trans-Atlantic invasion from South America.

Fall armyworm IPM programme

2.1.6 Harnessing FAW monitoring data to guide IPM of FAW in Eastern Africa

- *icipe* in collaboration with FAO Fall Armyworm Monitoring and Early Warning System (FAMEWS) continues to explore the open-source data available from the platform to analyze the key drivers of FAW bio-ecology, particularly the cropping system, crop diversity, effect of rainfall patterns, crop vegetative stages and FAW population dynamics.
- Data collected from five East African countries (Kenya, Uganda, Rwanda, Ethiopia and Tanzania) showed that the amount of rainfall was the principal driver affecting FAW density along with the maize cropping calendar in each respective country.

2.1.7 Estimating crop losses from Fall armyworm (FAW) in Kenya

- Estimates of crop losses due to FAW are essential in order to compare the impact of these losses with the cost of controlling FAW to inform appropriate technology dissemination and policy.
- In Kenya, crop losses due to FAW in 2018 showed that losses in the low- and medium-potential areas were less (20%), but the high-potential areas were now more affected (33%).
- Results showed that FAW has become the major pest of maize in Kenya, causing losses of a third of the annual maize production, estimated at about 1 million tonnes.

2.1.8 Diversity of invasive FAW and its gut bacterial community in Kenya

- Investigated the composition, abundance and diversity of microbiomes associated with larval and adult specimens of FAW collected from four maize growing regions in Kenya through high throughput sequencing of bacterial 16S rRNA gene.
- Identified Proteobacteria and Firmicutes as the most dominant phyla and lesser proportions of Bacteroidetes and Actinobacteria. Several bacterial groups were found in both adults and larvae suggesting that they are transmitted across developmental stages.
- Observed reads corresponding to several known entomopathogenic bacterial clades as well as the non-bacterial entomopathogen, *Metarhizium rileyi*.
- Mitochondrial DNA haplotyping of FAW population in Kenya indicated the presence of both 'Rice' and 'Corn' strains, with a higher prevalence of the 'Rice' strain. Insights into the microbiota may ultimately provide alternative avenues to control this pest.

2.1.9 Developing, commercializing and scaling of biopesticides for integrated FAW management

- In Kenya, dossiers were submitted for commercial registration of *Metarhizium anisopliae* ICIPE 78 (Achieve®) as biopesticide against FAW, and a field efficacy trial permit was obtained from Pest Control Products Board (PCPB) for its label extension. Dossier for *M. anisopliae* ICIPE 7 (Tickoff®) was submitted to PCPB to fast-tract registration for the product as Mazao Detain® against FAW.
- In Tanzania dossiers for ICIPE 7 and ICIPE 78 have been submitted to National Biological Control Programme (NBCC) for their registration.

- In Uganda, field efficacy trial permits have been granted for ICIPE 7 and ICIPE 78 by the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) through Crop Inspection and Certification Board (CICB).
- Multilocational field efficacy trials have been established in Kenya and are planned for Tanzania and Uganda for the April 2020 maize cropping season.
- Additional isolates *Beauveria bassiana* ICIPE 621 and *M. anisopliae* ICIPE 7 have been found to be highly pathogenic and virulent to adult FAW and compatible with FAW pheromone Falltrack®.

Integrated pest and pollinators management

2.1.10 Integrated pest and pollinators management (IPPM) to enhance productivity of avocado and cucurbits among smallholder growers in East Africa

- The distribution and abundance of avocado pests and pollinators was modelled for the first time in Africa, and what drives the performance of IPM, pollination services (PS) and IPPM has been established.
- In low vegetation landscapes honeybees were predominant, while in high vegetation other pollinators were present in high densities.
- Pest (fruit fly and false codling moth) densities were much higher in low than in high vegetation landscapes. Pest populations were drastically reduced by IPM, PS and IPPM treatments across all landscapes, especially in low vegetation landscapes.
- In Muranga, pollinator supplementation with two beehives/farm resolved the pollination deficit of 27% completely in high and medium vegetation landscapes, while in low vegetation landscapes pollination deficit was reduced to only 4%, resulting in an elevated income of US$168/farmer/season.
- Ex-ante studies revealed great potential for IPPM adoption. Access to extension services and adequate training have shown a profound effect on adoption and willingness-to-pay for IPPM services.

Thrips Programme

2.1.11 Development of pheromone blends as alternative to insecticides for control of thrips on legumes

- The bean flower thrips (BFT) *Megalurothrips sjostedti* is the primary pest of cowpea in SSA.
- During the period under review, the aggregation pheromones of BFT was characterized.
- Gas chromatography-mass spectrometry analyses of headspace samples resulted in identification of two compounds mediating aggregation of the pest, namely (*R*)-lavandulyl 3-methylbutanoate (major) and (*R*)-lavandulol (minor) observed from male BFT.
- This is the first report of a male-produced aggregation pheromone in the genus Megalurothrips**.**

Termite management programme

2.1.12 Biopesticide development to manage termites

- Termites attack a diversity of agricultural crops at all the growth stages.
- *Metarhizium brunneum* Cb15-III has been identified as an excellent candidate of entomopathogen for the management of destructive termites. Termites use CO_2 to locate plant roots.
- The team has formulated a CO_2-emitting capsule that is combined with Cb15-III for controlling the pest. In a choice test, significantly higher number of termites were attracted to capsules with Cb15-III (CEC_{EPF}) than capsules without the fungus (CEC) applied to cocoa seedlings, dry wood and yeast.

Citrus integrated pest management

2.1.13 Strengthening Citrus production systems through the introduction of IPM measures for pests and diseases in Kenya and Tanzania (SCIPM)

- The presence of the more aggressive and heat tolerant form of causal agent of citrus greening disease (Huanglongbing), *Candidatus* Liberibacter *asiaticus* (Las) in Kenya and Tanzania was confirmed.
- This discovery alerts us on an imminent and major threat to citrus production in the lowlands and to the entire citrus industry on the continent.

- Coupled with this finding is the first detection of *Diaphorina citri,* the main vector of the citrus greening disease, in Ethiopia, Kenya and Uganda.
- The union of both the disease and its vector in Africa increases the danger of a citrus industry collapse similar to the challenges faced by growers in Florida, USA if appropriate measures are not put in place to address the menace.
- The team has modelled the potential areas for invasion/establishment of the greening disease using MaxEnt, BIOCLIM and Boosted regression trees and results showed that many African countries are suitable for the establishment of the disease.

Insects for Food and Feed (INSEFF)

2.1.14 Testing Business Models for Scaling Insect-Based Protein Feed for Use in Poultry Farming and Aquaculture in Kenya (SiPFeed) and Insect feed for poultry, fish and pig production in Kenya and Uganda (INSFEED Phase II)

- Black soldier fly (BSF) colonies in *icipe* have sufficiently been boosted to meet the demand from large-scale farmers.
- The BSF larvae (BSFL) reared on combination of pig manure and potato waste were 12% heavier than those reared on barley waste.
- Four (4) new demonstration facilities have been established in Makuyu, Limuru, Rongai and Kamiti in Kenya with a minimum production estimate of 2 tons/month.
- An interactive insect-based protein feed production and marketing information exchange platform to link actors along the value chain has been initiated to allow stakeholders to capture feedback in real time from various insect production and supply systems.
- Macro-economic studies revealed that there is potential for replacing the conventional protein sources (fish meal and soybean meal) of the entire poultry sector in Kenya by 5-15% with black soldier fly larvae (BSFL) feed which is estimated to generate a total benefit of US$26-77 million per year, representing 0.04-0.12% of Kenya's GDP.

2.1.15 Effects of black soldier fly (BSF) frass-fertilizer on the growth, yield and nitrogen-use efficiency of maize in Central Kenya

- The application of BSF frass-fertilizers significantly increased maize grain yields compared to the other fertilizers. Plots treated with 100 kg N ha^{-1} BSF frass-fertilizer produced the highest maize grain yield of 5.7 t ha^{-1}, which was 6% higher compared to that produced by SAFI (commercial fertilizer) and Urea (chemical fertilizer) treated plots.
- Agronomic N use efficiency (kg of grain produced per kg of N applied) of maize in BSF frass-fertilizer treated plots was 27% and 116% higher compared to that grown in SAFI and Urea treated plots, respectively.

2.1.16 Oils extracted from Afro-tropical edible insects as potential sources of nutra- and pharmaceuticals

- Coupled gas chromatography-mass spectrometry (GC-MS) and coupled liquid chromatography (LC)-MS were used to compare compositional differences of oils of selected traditionally consumed edible insects found in Africa.
- The oils were obtained from optimized aqueous extracts of insects representing three orders: Orthoptera, Diptera and Lepidoptera. The insect oil compositions were compared with those of two commercially produced plant oils [Olive (*Olea europaea* L.) and Sesame (*Sesamum indicum* L.)].
- Combining these two analytical methods led to the identification of more than 70 compounds, which are beneficial for human nutrition and health including vitamin E, fatty acids and antioxidants. Most of these compounds have not been reported previously in insect oils.

2.2 ANIMAL HEALTH THEME

Camel Health programme

2.2.1 Developing technologies and strategies to control vectors of camel diseases

- Identified nectar feeding habits of stable flies and exploited the same in bait technology development.

- "Preference-performance" hypothesis in *S. calcitrans*, with gravid females showed that by using dual and multiple-choice oviposition bioassays, gravid female *S. calcitrans* avoided substrates with conspecific larvae, the larvae of house flies, *Musca domestica*, and the mite *Macrocheles muscaedomesticae*.
- Avoidance of conspecific and heterospecific larvae persisted in the dark, suggesting that this behavior is mediated by chemical rather than visual cues.
- When reared *S. calcitrans* was reared in the presence of conspecific larvae and the larvae of house flies at different densities, emergence time, larval weight, larval survival, pupal weight, pupal survival, and adult weight were negatively affected.
- Demonstrated that individuals of *S. calcitrans* that developed in the presence of mites exhibit low egg hatchability, and poor larval and adult survival.
- This study provides additional support for the "preference-performance" hypothesis in *S. calcitrans*, with gravid females preferring to lay eggs on a substrate that will enhance offspring fitness.

2.2.2 Developing low cost, low environmental impact control technologies for camel diseases vectors

- Integrated *surra* and its vectors management (ISVM) tool consisting of four components (attractants, repellents, diagnosis, and treatment) was developed. A novel repellent collar (formulated on nano beads for slow release from the wooden collar) has been developed and farmers in Isiolo and Marsabit Counties of Kenya were trained on the use of ISVM tool.

Tsetse control and management

2.2.3 Integration of tsetse repellent technology to limit African Animal Trypanosomiasis (AAT)

- Licensing agreement signed with private sector partner (Innova Biologicals Ltd) for the commercialization of the repellent collar (collar and repellent blend).
- A cloud-based mobile phone application (named LiMA) to link farmers to retailers of the repellent technology (collar and blend) developed. Trademark application for LiMA is progressing with regulators.
- Community Owned Resource Persons (CORPs) in Kwale on the use of LiMA for linking with farmers and sourcing veterinary products (e.g. repellent collar and blend) trained and collaboration with private sector strengthened.
- Project area extended with data collected from Homa Bay County, western Kenya, and preliminary activities were carried out in Zambia and Ethiopia (Benshangul Gumuz).

2.2.4 Improving food and nutritional security through integrated control of tsetse and tick-borne livestock diseases (ICTLD)

- Registration dossier for bioacaricide (Mazao Tickoff) submitted to Kenya Veterinary Medicines Directorate (VMD).
- Trial protocol for Randomized Controlled Trial (RCT) for tick bioacaricide submitted to VMD for implementation in Kilifi County.

2.2.5 Novel repellent blend identified from zebra odours

- Analysis of zebra skin odours resulted in identification of seven electrophysiologically-active components and compounds that elicited repellency to *Glossina pallidipes*, an efficient vector of livestock trypanosomes.
- A blend containing three components: 6-methyl-5-hepten-2-one, acetophenone and geranylacetone caused a 62.7% reduction in trap catch of *G. pallidipes* in the field.

2.2.6 Developing a new generation trypanosomes transmission blocking by selectively trapping or repelling trypanosomes positive tsetse flies

- Trypanosoma induced biomarkers were identified for diagnosis of animal trypanosomiasis.
- A simple, non-invasive biomarker based African animal trypanosomiasis (nagana) diagnostic tool was developed and its application for surra (camel trypanosomiasis) diagnosis is ongoing.
- Field and laboratory trials are also ongoing to evaluate trypanosomes induced biomarkers attractivity to infected flies.

Capacity Building in Animal Health

2.2.7 Eastern Africa Network of Bioinformatics Training – EANBiT Project

- This collaborative network was established to strengthen the application of bioinformatics in biosciences research through individual training, research mentorship and enhancing institutional capacity in East Africa.
- One of the key objectives was to establish a harmonized MSc Bioinformatics program at three universities in East Africa (Pwani University in Kenya, Makerere University in Uganda and Muhimbili University of Health and Allied Sciences in Tanzania).
- The programme has now started at both Pwani and Makerere universities, with MUHAS expected to start in 2020. The first cohort of 10 students are now in their project phase, with two of these undertaking their project work at *icipe*.
- The bioinformatics team is actively engaged in developing and adapting data stewardship strategy and tools for efficient acquisition and management of information (including REDCap, Baobab LIMS).

2.2.8 Established capacity and collaboration for studying insect vision for improving tools for disease vectors and pest control

- In the last year, we have established capacity to study insect vision through photo- spectrometry and colour-opponent modelling of insect vision to develop more efficacious visual baits for disease vectors and pests through physiologically inspired models and fabric engineering.
- Using data that were previously collected in Kenya, modelling efforts demonstrated that predicted colours engineered into synthetic fabric attract more tsetse than with other existing tools.

2.3 HUMAN HEALTH THEME

2.4.1 SymbioVector Project

- 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://go.nature.com/2xwzbyl). 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.
- With collaborators from Wellcome Sanger Institute, we have used single cell RNA-sequencing to investigate expression of genes by the *Plasmodium* parasite over the course of its life cycle and to create a "Malaria Cell Atlas". Results from this study were published in the journal, *Science*.

2.4.2 Eco-toxicological investigations of freshwater pollution on the distribution and vector competence of Schistosoma host snails in freshwater streams in western Kenya

- Schistosomiasis, an acute and chronic parasitic disease caused by trematode worms of the genus Schistosoma, affecting the poorest of the poor with infections, particularly abundant among people living in rural or deprived urban or peri-urban settings.
- We found that snails (and particularly the Planorbid host snails) were highly tolerant to neo-nicotinoid and organophosphate insecticides.

- The incidence and the density of snails increased with agrochemical pollution. Additionally, with increasing agrochemical pollution, snail communities became more dominated by the Planorbid host snails.
- These findings indicate that agrochemical pollution is a relevant driving factor for the risk of infection with schistosomiasis.

2.4.3 Prevalence, intensity and risk factors of tungiasis in Kilifi County, Kenya

- Tungiasis is a disease caused by the female sand flea which burrows into the skin of the feet and causes intense pain and itching.
- A risk factor study was published in May 2019. The feet of 1,829 students of all age groups from 5 schools in coastal Kenya were examined.
- The overall prevalence of tungiasis was 48%, with boys between the ages of 10 and 14 years at most risk and factors related to socio-economic status were found to be positively associated with disease risk.
- Results indicated that up to 70% of tungiasis cases may be prevented through simple prevention methods.
- There is a clear role for public health workers to expand the Water, Sanitation and Hygiene (WASH) policy to include washing of feet with soap in school-aged children to fight tungiasis and raise awareness of the importance of sealed floors.

2.3.4 Evaluating the feasibility and impact on malaria transmission of community-based winter larviciding or house screening as additional vector control interventions in southern African countries committed to malaria elimination (AFRO-II Project)

- AFRO-II aims to demonstrate the potential added benefit of integrating currently readily available but not-widely used vector control tools, namely winter-larviciding and house screening, in six southern African countries (Botswana, Namibia, Swaziland, Mozambique, Zambia and Zimbabwe) that are attempting a final push at malaria elimination. Ethical clearance approvals for all these six countries were finalised.
- In-country teams trained in methods for entomological, epidemiological and socio-economic assessments in Namibia, Swaziland, Zambia, Mozambique and Botswana.
- Baseline household data collection finalized in Zambia and Mozambique and commenced in Namibia, Swaziland and Botswana and data are being analysed.
- Screening of households completed in Mozambique and it is on-going in Zambia.

2.4.5 An assessment of risk of Yellow fever and dengue virus transmission in selected dry ecologies and major cities of Kenya

- The seroprevalence of key mosquito borne *Flaviviruses* namely Zika, Dengue, Yellow Fever (YF) and West Nile infections in asymptomatic human population from West Pokot and Turkana Counties of Kenya, which border Uganda, South Sudan and Ethiopia is being assessed.
- These countries have recently reported that YF/dengue outbreaks are presenting possibility for spillover. We found evidence of human exposure to these viruses at varying levels in West Pokot and Turkana with higher seroprevalence of Zika virus in West Pokot (7.1%) than in Turkana (0.2%) and higher seroprevalence of YF in Turkana (10.7%) than in West Pokot (1.3%).
- Antibodies to West Nile (Turkana) and Zika (West Pokot) viruses were detected in the younger age group indicating recent low-level transmission in the test areas.

2.3.6 Arboviruses

- Simian immunodeficiency virus (SIV) naturally infects African non-human primates (NHPs) and poses a threat of transmission to humans through hunting and consumption of monkeys as bushmeat.
- The study investigated the as yet unknown molecular diversity of SIV in free-ranging *Chlorocebus* species (African green monkeys-AGMs) and *Papio anubis* (olive baboons) within Mombasa, Kisumu and Naivasha urban centres in Kenya.
- Simian immunodeficiency virus prevalence was 32% in AGMs and 3% in baboons. High-resolution melting (HRM) analysis demonstrated distinct melt profiles illustrating virus diversity confirmed by phylogenetic analysis.

2.4 ENVIRONMENTAL HEALTH THEME

Scaling up beekeeping and silkworm farming

2.3.1 The Young Entrepreneurs in Silk and Honey (YESH) Project

- The Young Entrepreneurs in Silk and Honey (YESH) project supported by the Mastercard Foundation aims to create employment opportunities for young people through beekeeping and silkworm farming in Ethiopia.
- YESH project, has met its target of recruiting 12,500 direct beneficiary youth (10,000 youth partners in apiculture and 2,500 in sericulture) with the addition of 3,800 youth in 2019.
- A major increase in honey and beeswax product and harvest (17 metric tonnes) was recorded by the youth enterprises during this harvest season, following intensive technical backstopping and mass bee colony multiplication activities.
- Efforts are now focussing on consolidation and planning towards realising the projects goal of ensuring that the beneficiaries become successful entrepreneurs and contribute to Ethiopia's continued economic growth.
- Following the success of the project, *icipe* was invited by the Mastercard Foundation to respond to a call for Expression of Interest for geographical expansion of the YESH project (see 2.3.2 below).

2.3.2 MOre Young Entrepreneurs in Silk and Honey (MOYESH) programme

- ***icipe*** in partnership with the Mastercard Foundation and Ethiopia Jobs Creation Commission (JCC), launched (31 October 2019) the US$55.6 million, five-year initiative that aims to see 100,000 young men and women in Ethiopia secure dignified and fulfilling work along honey and silk value chains known as More Opportunities for Young Entrepreneurs in Silk and Honey (MOYESH) Programme.
- Following the national programme launch in Addis Ababa, MOYESH was officially launched in the four programme sites; Jimma town in Oromia Region on 12 January; Hawassa for SNNP Region on 17 January; Bahir Dar for Amhara Region on 18 January and Tigray Region on 1 February 2020.
- Selection and validation of programme intervention Zones (16 in total) and Woredas (40 in total) was completed.

2.3.3 Scaling up Quality Honey Production and Fair Trade in Ethiopia

- Construction of eight additional honey and beeswax aggregation and processing marketplaces was completed, increasing the total to 13 marketplaces.
- Three successful honey festivals were held in three high performing districts, combined with visits to model youth enterprise apiaries and panel discussions.

2.3.4 Alternative livelihoods for food and income security in four Indian Ocean Island Nations (Mauritius, Seychelles, Comoros and Madagascar) and in Zanzibar (United Republic of Tanzania)-Phase 2

- The goal of the project is to contribute towards increasing food security and income generation opportunities for smallholder farmers through improved beekeeping technologies and pollination services.
- The project launch meeting was held in Antananarivo, Madagascar in 13-14 June 2019 and an advanced course on bee pests and diseases was organized for the 10 selected participants of the Island States partner organizations and one representative of the National Animal Health Diagnostic and Investigation Center, Ministry of Agriculture, Ethiopia in *icipe* on 18-24 August 2019.
- The course enables participants comprehend the impact of pests and diseases on bee health, to develop skills on their identification and diagnosis, provide knowledge and build ability to use tools for bee pest and diseases management through theoretical and practical (hands-on) training sessions in the laboratories.

Stingless bees R&D

2.3.5 Stingless bee species discrimination using landmarks and molecular tools

- Based on body morphology, two potential new species have been noted from samples collected in Kenya. Additionally, two species that are no longer being mentioned in literature have been identified in samples collected in Zanzibar and west Africa regions.
- DNA barcoding is being conducted to confirm the two new species and revive knowledge on the other two species that are no longer being mentioned in literature.

2.3.6 Pollination efficiency among different stingless bee species in relation to fruit set, yield and seed quality on cucumber and bell pepper

- A comparative study was conducted to assess bee foraging behaviors and pollination efficiency in relation to fruit production and seed quality set on greenhouse cucumber and yellow bell pepper. Four categories of treatments (no pollination, self-pollination, hand cross-pollination and bee pollination) were employed.
- Results indicated that green pepper female flower pollinated by *Hypotrigona gribodoi* were 5% bigger and had more seeds than plants that were self-pollinated, hand cross-pollinated and pollinated by the honeybee and other stingless bee species.
- Cucumber female flower pollinated by *Meliponula ferruginea* were 10% bigger and had more seeds than those that were self-pollinated, hand cross-pollinated and pollinated by the honeybee and other stingless bee species.

2.3.7 Stingless bee species honey quality analyses

- In ongoing studies, we are analyzing the bio-functional properties of stingless bee and honeybee honey samples from across Africa, South America, Asia, and Europe.
- Comparison between African stingless bee honey (SBH) with that of honeybee honey (HBH) showed that the SBH is richer in phytochemicals.
- For instance, SBH has phenol content of 166.55 GA E/100g while HBH has 98.37 GA E/100g.
- The flavonoid content for SHB is 66.31 Q E/100g, which is almost four times more. These properties can be attributed to the high medicinal value of SBH compared to HBH.

Bee Health

2.3.8 Bee gut microbiota

- The bee gut microbiota from sub-Saharan Africa is composed of the same core members although their abundance and prevalence differ with previous studies done in the north (Europe and USA).
- By conducting whole genome sequencing of one of the African prevalent bacterial members (*Acetobacter Commensalibacter sp.*) we uncovered that it lacks the capability of fermentation but instead harbours a diverse set of cytoplasmic dehydrogenases and the loss of the tricarboxylic acid (TCA) cycle. We speculate that the broader metabolic range may represent an advantage in the worker bee hindgut, where competition with other bacteria and flexibility in resource utilization may be more relevant for persistence.
- We have evaluated the effect of *Lactobacillus kunkeei* in bee immunity and protection against opportunistic bacteria. Preliminary results showed that when bees are mono-inoculated (colonized only by one bacterium in their gut) with *L. kunkeei*, this bacterium activates an innocuous immune response that protects the bee against opportunistic bacteria. We are currently confirming such findings and evaluating other potential protective bacterial isolates from our established library.

2.3.9 The invasion of the dwarf honeybee, Apis florea, along the river Nile in Sudan

- Assessed the invasive potential of the dwarf honeybee, *Apis florea*, a highly mobile species native to Asia, introduced into Sudan spreading northwards along the river Nile potentially threatening the native *A. mellifera.*
- Results showed no indication of competitive displacement. Molecular analyses indicated that a single colony was introduced three decades ago.

Pollination

2.3.10 Landscape characteristics and pollinators

- Understanding the linkages between landscape characteristics and honeybee colony integrity is fundamental in addressing issues related to pollinator decline.
- Results from mapping approach showed that fusing data generated from S1 (dual-polarized multi-season Sentinel-1A synthetic aperture radar {SAR}) and S2 (single season Sentinel-2A optical imagery) with improved spectral resolution, could be effectively used for the spatially explicit mapping of honey bee habitats and their degree of fragmentation in semi-arid African agro-ecological landscapes.

3. PROGRESS REPORT ON SPECIAL PROGRAMMES

3.1 BioInnovate Africa Programme Phase II

- The Programme is providing innovation grants to 20 regional project teams in six participating countries, namely: Burundi, Ethiopia, Kenya, Rwanda, Tanzania and Uganda.
- To date, three project teams in cohort 1 and one project team in cohort 2, have validated their business models. They are receiving orders for their products and making test sales. These teams are: BA Project 11 (bioconversion technologies for wastewater treatment and biogas generation); BA Project 3 (certified clean sweet potato planting materials); BA Project 5 (nitrogen bio-fortified fertilizers; and BA Project 18 (bio-alkanol gel from fruit wastes). Additionally, BA Project 20 (developing a regional bioeconomy strategy) have developed draft version 1.1 of a regional bioeconomy strategy for eastern Africa through active engagement with policy makers and other stakeholders in the six participating countries.
- Products being commercialized broadly include: nutrient enriched biofertilizers, improved crop varieties, insect derived proteins for food and feed, integrated microbial and constructed wetland industrial waste water treatment system, enzymes for de-haring hides and fish scales, post-harvest management technologies for pest disinfestation and drying fruits and vegetables, processed food and nutritional products from sorghum, millet and sweet potatoes, biorefined products from agricultural residues and novel biochemical compounds for pest and vector control.
- The Programme is implementing a 4 – 6 months Fellowship for Women Scientists. So far, 12 Fellows from five countries have completed the Fellowship; an additional 12 are undertaking the Fellowship in various organizations in the region. Fellows learn design and implementation of innovation projects.

3.2 The Partnership for skills in Applied Sciences, Engineering and Technology (PASET) - Regional Scholarship and Innovation Fund (RSIF)

The objective of RSIF is to build high quality doctoral training, research, and innovation capabilities in priority technology areas, including new transformative technologies, important for Africa's development. Priority areas include: ICTs, including big data and artificial intelligence; Food security and agribusiness; Energy, including renewables; Minerals, mining and materials engineering; and Climate change. During the period under review, the team accomplished the following:

3.2.1 Capacity building and professional development of African scientists

- *icipe* took over the management of first cohort of 16 RSIF PhD scholars from the Association of African Universities (AAU). These students are enrolled in various fields of applied sciences, engineering and technology, namely food security and agribusiness (8[2]); climate change (2); digital technologies, including data science and artificial intelligence (2); energy (none in first cohort); and minerals, mining and materials engineering (4).
- Concluded a Call for second cohort of RSIF scholars. A total of 1,700 applications were received. The selection process for the 2nd cohort of RSIF scholars was done and finalised (42 men, 29 women).
- Trained 15 RSIF scholars on research communications, digital storytelling, research ethics,

[2] One of the RSIF scholars who was enrolled at SUA, Lillian Mulewa Robert from Kenya, has resigned from the programme.

information literacy, reference management and open access e-resources.

- Matched 12 RSIF scholars to sandwich training with international partner institutions; six with the Korean Institute of Science and Technology and another six with Worcester Polytechnic Institute in the United States.
- Initiated development of the gender strategy for PASET with special attention to women and underrepresented groups, seeking to promote family friendly policies, language and accessibility measures.

3.2.2 Institutional development by nurturing and strengthening African research and higher education institutions.

- *icipe* made presentations on RSIF to ministers and technical experts at the 3rd Specialized Technical Committee on Education, Science and Technology (STC-EST 3) at the African Union Headquarters in Addis Ababa.
- Conducted visits to the University of Gaston Berger (UGB), Senegal; University Félix Houphouet-Boigny (U-FHB), Côte d'Ivoire and the University of Ghana and met with university leadership, key departmental staff and students to engage in discussions about partnership, capacity building and student matching.
- Stakeholder meeting has been co-organised by *icipe* and the Government of Benin on opportunities for PhD training, research collaboration and innovation under RSIF held in Cotonou, Benin.
- Grant writing workshop held at *icipe* for faculty members from 16 African universities from 9 sub-Saharan African countries, building their capacities in grant/project development, implementation and impacts.
- ICT survey was carried out amongst RSIF African Host Universities to assess the status of ICT facilities to inform the RSIF Capacity Building Strategy including the establishment/strengthening of video conferencing facilities at universities.
- Calls for RSIF innovation grants and research awards published and eligibility screening undertaken.
- Facilitated the selection of seven[3] new RSIF African Host universities bringing to 11 the number of African Host Universities (AHUs) for the RSIF.
- Engaged various international partners (including 15 international universities/institutions in Europe, North America, Brazil) to bring on board strong institutions to engage in joint research and training and raise the level of PhD training for the program through institutional capacity building of the AHUs, including support to processes for accreditation.
- Initiated the development of tools to undertake a scoping study to establish the status of research and training at AHUs and related key services, such as ICT services and facilities, access to journals, and fiduciary processes.
- Supported visit of six (6) African host universities (Bayero University Kano (BUK); Kenyatta University (KU); The Nelson Mandela African Institution of Science and Technology (NM-AIST); Sokoine University of Agriculture (SUA) ; University of Ghana (UG); and University of Nairobi) to Japanese universities and to learn about university-industry linkages.
- Facilitated visit of representatives from 11 African Host Universities to the University Mohamed 6 Polytechnic (UM6P), Morocco to identify areas for research collaboration and student sandwich training.
- Launched call for proposals to the Institutional Innovation Capacity Building Programme (RSIF-ICBP) Grants. The ICBP grant's aim to help RSIF African Host Universities develop a conducive environment that supports innovation and entrepreneurship development within the University.
- The team is managing and grew the general fund from US$13 million to US$14 million. The team is also in the process of commissioning a firm to do a feasibility study for the establishment of a permanent endowment fund for the RSIF, in line with the long-term vision of growing the RSIF into a sustainable Pan-African science fund.

[3] Kenyatta University is currently suspended due to confusion on the accreditation status of the selected PhD programme.

4. CAPACITY BUILDING AND INSTITUTIONAL DEVELOPMENT (CBID) PROGRAMME

icipe considers building the capacity of individual researchers, institutions and communities in Africa as integral to its research and sustainable development activities. During 2019, *icipe* has continued to make a significant contribution to building the capacity of people through the development of MSc, PhD, postdoctoral and research intern capabilities, and institutions through various projects and activities including RSIF-PASET. *icipe* also continues to conduct trainings for researchers, farmers, national programme partners and others in knowledge intensive areas of *icipe* technologies and products.

***Pursuing gender equity*:** 46% of postgraduate scholars in the programme are women, while the women's representation is highest in the DRIP MSc programme (53%). Representation by women was lowest in the postdoctoral programme (13%).

***The programme has continent-wide representation*:** 18 African nationalities (Benin, Burkina Faso, Burundi, Cameroon, Congo, Ethiopia, Ghana, Kenya, Nigeria, Rwanda, Senegal, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe) were represented in the postgraduate and postdoctoral programmes during the reporting period.

***ARPPIS PhD scholarships 2020*:** *icipe* was once again selected to participate in the DAAD PhD scholarship programme. *icipe* was one of 15 successful institutes/universities selected from 88 applicants. DAAD has offered up to 6 new PhD scholarships for the ARPPIS programme in 2020.

icipe Information Resources Centre (IRC): The IRC spearheaded the registration of 11 RSIF African Host Universities (AHUs) to *Research for life* which provides access to over 20,000 peer reviewed journals for free. It facilitated all RSIF AHUs to register and attend a free five-week research4life Massive Open Online Course (MOOC) that focused on training librarians to market and train users on HINARI, AGORA and OARE to increase usage. The IRC acquired new e-resources i.e. Sage research methods, Taylor and Francis journals, OECD library and Project Muse e-library through the Kenya Libraries and Information Services Consortium (KLISC).

5. PUBLICATIONS

Peer reviewed publications: In 2019, *icipe* has published 143 peer reviewed journal articles. The complete report on publications is provided in **Annex 1**. One of the major publications during the period under review is a research article by Howick VM, Russel A, Andrews T, Heaton H, Reid AJ, Natarajan KN, Butungi H, Metcalf T, Verzier LH, Rayner J, Berriman M, **Herren JK**, Billker O, Hemberg M, Talman A and Lawniczak M (2019). *The Malaria Cell Atlas: a comprehensive reference of single parasite transcriptomes across the complete Plasmodium life cycle,* published in the journal, *Science*. The authors envision that the Malaria Cell Atlas will support the development of much-needed new drugs, vaccines, and transmission-blocking strategies.

Non-peer reviewed publications: In 2019 *icipe* published 151 publications that are non-peer reviewed but are of significant scientific value. This include books; book chapters; conference papers; policy briefings; case studies/thematic summaries; toolkits and procedures; training manuals and brochures as well as posters.

International Journal of Tropical Insect Science (IJT): In December 2018, *icipe* oversaw publication of the final issue of the *International Journal of Tropical Insect Science* before handing over the management of the journal to the African Association of Insect Scientists (AAIS) on 1st January 2019. The journal also moved from Cambridge University Press to a new publisher, Springer. To ensure a smooth transition, *icipe* provided technical support to the new team at AAIS, including training on the online journal management system and general day-to-day journal operations. This has helped to maintain the journal's high standards, including completion of all issues ahead of schedule, and an increase in the impact factor to 0.85.

6. COMMUNICATIONS AND MEDIA

Social Media statistics

During this period, *icipe* was mentioned in media in over 69 countries. Most of this coverage is available online with many of the items reproduced, on average, by five additional outlets (beyond the initial publisher or broadcaster). As is always the case, the Centre was featured in almost all Kenyan media and across Africa. The top international media that covered *icipe* research includes: Radio France International, Transafricaradio, International Business Times, Thomson Reuters News Agency, Allafrica.com, SciDev.Net, China.org.cn, Xinhua News Agency, Washington post, CNBC Africa, The Science Explorer, and Relief Web.

A summary of *icipe* social media statistics as captured by Meltwater Monitoring Services for the period, 1 January – 31 December 2019 is provided in Table 1.

Table 1. Summary of *icipe* media statistics during 2019

Quarter	Number of articles	Potential reach (Approx. number of article views)	Advertising value (US$)
Q4	67	47 million	435,300
Q3	114	107.2 million	991,700
Q2	107	78.2 million	723,600
Q1	156	147.3 million	1.36 million

icipe website: Approximately 105,000 visitors and 403,000 page views were registered during the reporting period. The top 11 countries (ranked in order of visitor numbers) are: Kenya, United States, Ethiopia, Belgium, Tanzania, Nigeria, United Kingdom, Uganda, South Africa, Germany, and India.

SECTION 3: Results Based Management (RBM) Framework: Programmatic Progress Report for 2019

7.1 Plant Health Theme: Results Based Management (RBM) Rolling Framework Report

<table>
<tr><th>Outputs</th><th>Outcomes</th><th>Performance Indicators</th><th>2019 Progress made in achieving the outcomes</th><th>2019 Lessons Learned</th></tr>
<tr><td colspan="5">Overall Objective: Increase horticultural and staple food production by at least 30% by 2020 by reducing pre- and post-harvest quantitative and qualitative losses due to pests in icipe's target areas.</td></tr>
<tr><td colspan="5">Objective: Develop and implement 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 2020.</td></tr>
<tr><td>1. Biopesticide for thrips IPM developed and commercialised.
2. Bean Flower thrips pheromone blend optimised.
3. Thrips IPM strategies based on intercropping, use of biopesticides, semiochemicals and botanical pesticides developed.</td><td>• Thrips and tospovirus management strategies for French bean, onions, tomato and grain legumes encompassing at least two IPM components formulated by 2020.</td><td>• At least one tospovirus-resistant cultivar of onion and tomato identified by 2017.
• Reduction in use of synthetic pesticides by at least 20% by 2020.
• Number of peer reviewed publications.</td><td>• Mazao Campaign® Metarhizium 69 has been fully registered in Uganda for thrips and fruitfly management.
• Two postdoc trainings on bean flower thrips pheromone optimisation have been completed.
• 1 publication on bean flower thrips pheromone characterisation completed (Niassy et al. 2019. Journal of chemical ecology 45, 348-355).
• Optimisation on release rates for the pheromone components optimisation of blends undertaken in the laboratory.
• Repellent activity of volatiles from botanicals such as Cymbopogon citratus and Tagetus minuta and resistant cowpea cultivar demonstrated (Diabete et al., 2019. Journal of Applied Entomology 143, 855-866; Diabete et al. 2019. Chemoecology 29, 73-88).</td><td>• Responses of bean flower thrips to pheromone blends were highly variable.
• There is need to more detailed assessment on the factors influencing the efficacy of bean flower thrips pheromone before development of a commercial product.
• Plant volatiles could be further exploited for bean flower thrips management.</td></tr>
<tr><td>4. Field efficacy and use of bean flower thrips pheromone standardised.
5. Field demonstration of thrips IPM strategies based on intercropping, use of biopesticides, semiochemicals undertaken.
6. IPM technology adapted and validated with grain legume farmers.
7. Ex-ante and ex-post assessment of the introduced.</td><td>• Awareness on thrips, tospovirus monitoring and management strategies created among agricultural extension officers/plant quarantine inspectors.
• French bean, tomato, onion and grain legume farming enhanced by 2015.</td><td>• Awareness among at least 200 agricultural extension officers/plant quarantine inspectors enhanced on thrips and tospovirus monitoring/ management by 2015.
• Awareness among at least 1,000 French bean, tomato, onion and grain legume farmers enhanced for adoption of the thrips and tospovirus management strategies by 2015.
• French bean, onion, tomato and grain legume yields increased by at least 15%.
• Rejection of French beans reduced by at least 10% in local, urban and export markets by 2015
• Number of training reports.
• Popular articles, mass media reports.
• Number of peer reviewed publications.</td><td>• Field efficacy of bean flower thrips pheromone components assessed at different concentrations and blends in Mbita and Mwea.
• Compatibility of bean flower thrips pheromones and entomopathogenic fungi assessed. BFT pheromones were incompatible with the Biopesticides.</td><td>• Responses of bean flower thrips to pheromone blends were highly variable.
• Further efforts to address incompatibility of BFT pheromones with biopesticides needs to be addressed.</td></tr>
</table>

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
management strategies.				
Objective: Development of sustainable management strategies for insect vectors of maize lethal necrosis disease (MLND) in East Africa by 2018.				
1. To identify and understand ecology of potential vectors responsible for transmission and spread of viruses causing MLN in East Africa. 2. To develop novel, effective and sustainable seed treatment strategies for the management of MLN. 3. To develop innovative and effective crop diversification strategies that influence both vector ecology and virus epidemiology.	• Integrated pest management strategies for key vectors of viruses causing MLN developed, through seed treatment, use of biopesticides and crop diversification techniques by December 2015.	• At least one key vector of Maize chlorotic mottle virus (MCMV) /Sugarcane mosaic virus (SCMV) identified by September 2014. • Number of distribution maps of key vectors established by December 2014. • Seasonality and alternate hosts of key vector in MLN hotspot areas studied by June 2015. • Competence of key vectors to transmit viruses causing MLN published by November 2015. • At least two sustainable seed treatment strategies against MLN identified by December 2014. • Levels of systemic insecticide residues in corn, tassels and silk estimated and safety to honeybees assessed by December 2015. • At least two intercrops that reduce the incidence of key vectors and thereby MLN identified by December 2014. • Impact of crop rotations on vector population and thereby the MLN identified by December 2015.	• Efficacy of fungal-based biopesticides for management of thrips vectors and MLN published (Kiarie et al. 2019. African Journal of Education, Science and Technology 5, 1-10). • Fungal endophytes were demonstrated to impart systemic resistance against component viruses of MLN (Kiarie et al. Plants 9, 416).	• Fungal endophytes have the potential to offer systemic resistance to plant viruses.
Objective: Develop and implement integrated pest management strategies for production of important indigenous vegetables in Kenya and Tanzania by 2018.				
1. Socio-economic constraints and opportunities for value addition of amaranth, leafy cowpea and nightshades production and protection assessed.	• Awareness on AIV IPM strategies created among agricultural extension officers, plant quarantine inspectors and farmers by 2018.	• Baseline information on current growers' knowledge, attitude and practices (KAP) with regard to IPM and other AIVs production measures collected by 2014. • The effect of growers training on growers KAP evaluated by 2018. • Constraints and opportunities for AIVs' production and marketing evaluated by 2016. • Impact of AIV IPM technologies assessed by 2018.	• One manuscript published (Ntawuruhunga D, Affognon HD, Fiaboe, KK, Abukutsa-Onyango MO, Turoop, L, Muriithi BW. 2020. Farmers' knowledge, attitudes and practices (KAP) on production of African indigenous vegetables (AIVs) in Kenya. International Journal of Tropical Insect Science, 1-13).	• Conducted in three counties in Kenya, this study assessed the KAP regarding AIVs and their contribution on output/yield. While significant knowledge and positive attitude was observed, use of improved farming practices was limited. KAP in general did not influence AIVs output, however, use of improved farming tools and scale operations positively influenced AIIV yield. Capacity building through AIV production training and gender (male) were also positively associated with AIVs output.

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
Objective: African nightshade for capturing nematodes – using 'dead end trap crop' technology for tackling a new pest in East African potato production undertaken by 2019.				
1. PCN (potato cyst nematodes) characterised - characterisation of PCN species and pathotypes.	• PCN (*Globodera* spp.) identified to species level. • PCN populations from different regions established. • Pure populations of *Globodera* species established. • At least one pathotype identified.	• Number of PCN species identified. • Number of PCN populations established. • Number of resistant potato varieties selected.	• Activities completed by 2018. • Results have been published in: Chitambo O, Haukeland S, Fiaboe KKM, Grundler FMW. 2019. African nightshade and African spinach decrease root-knot nematode and potato cyst nematode soil infestation in Kenya. Plant Disease 103, 1621-1630.	
2. Dead-end trap crop identified - potential trap crops among indigenous solanaceous vegetables in Africa identified and tested.	• At least 5 trap crops identified for trapping PCN. • At least 2 trap crop species evaluated under field conditions.	• Number of trap crops selected for further evaluation. • Number of farmers involved in field testing using the selected trap crops.	• Activities completed by 2018. • Results have been published in: Chitambo O, Haukeland S, Fiaboe KKM, Grundler FMW. 2019. African nightshade and African spinach decrease root-knot nematode and potato cyst nematode soil infestation in Kenya. Plant Disease 103, 1621-1630.	
3. Roots and exudates analysed - susceptible/ resistance factors in selected trap crop roots and their exudates elucidated.	• Mechanisms and composition of root exudates analysed for at least 5 trap crops.	• Number of trap crops and their root exudates analysed and evaluated on PCN hatching and behaviour.	• Activities completed by 2018. • Results have been published in: Chitambo O, Haukeland S, Fiaboe KKM, Grundler FMW. 2019. African nightshade and African spinach decrease root-knot nematode and potato cyst nematode soil infestation in Kenya. Plant Disease 103, 1621-1630.	
4. Biopesticides selected – potent biopesticides for PCN controlled screened and identified.	• Selected biocontrol fungi comprising at least 2 different species evaluated against PCN under natural conditions. • Naturally occurring parasitic fungi in field populations of PCN identified.	• Number of biocontrol fungi selected as effective suppressors of PCN. • Novel species of fungi identified from Kenyan populations of PCN.	• Activities completed by 2018. • Results have been published in: Chitambo O, Haukeland S, Fiaboe KKM, Grundler FMW. 2019. African nightshade and African spinach decrease root-knot nematode and potato cyst nematode soil infestation in Kenya. Plant Disease 103, 1621-1630.	
5. Farmers trained - capacity building and technology transfer initiated with national agricultural research partners and potato growers.	• Partnerships with NARS established. • Joint stakeholder meetings conducted. • Students trained and graduated. • Farmers in main potato growing areas have obtained basic knowledge on PCN.	• Number of students trained/graduated. • Number of meetings held. • Number of farmers reached.	• Activities completed by 2018. • Results have been published in: Chitambo O, Haukeland S, Fiaboe KKM, Grundler FMW. 2019. African nightshade and African spinach decrease root-knot nematode and potato cyst nematode soil infestation in Kenya. Plant Disease 103, 1621-1630.	
Objective: Develop an agroecological farming system for horticultural crops profitable and adapted to smallholder famers with low environmental impact based on a netting technology adapted to tropical climate conditions combined with biological control technics, semiochemicals use and plant association by 2020.				

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
1. Study of the distance and contact host plant search and selection strategy in order to identify push and pull stimuli.	• *Tuta absoluta,* whitefly, *Nesidiocoris tenuis, Encarsia formosa* rearing. • Identification of volatiles emitted by healthy, leafminer- or whitefly-infested tomato of 4 varieties. • Identification of repellent and attractant volatile blend for leafminer and whitefly. • Identification of compound emitted by healthy, leafminer- or whitefly-infested tomato trichomes of 4 varieties. • Identification of repellent and attractant trichome compound blend for leafminer and whitefly. • Identification of companion plant.	• Number of colonies. • Number of semiochemicals blend. • Number of identified companion plant.	• 1 article has been submitted on the effect of companion plants. • The work on whitefly and *Tuta absoluta* has been delayed as the chemical ecology lab was not functional for 9 months.	• Basil and marigold are good trap crops for whitefly.
2. Promotion of biological control.	• Identification of natural enemies of leafminer and whitefly in Kenya. • Study of the effectiveness of the use of 1 predator and 1 parasitoid. • Identification of attractant semio-chemicals for natural enemies from tomato. • Identification of attractant semio-chemicals for natural enemies from the prey/host. • Identification of companion plant to attract natural enemies.	• List of identified natural enemies.	• A PhD study is ongoing. • The work on whitefly and *Tuta absoluta* has been delayed as the chemical ecology lab was not functional for 9 months.	• False sesame is a good insectarium plant for Nesidiocoris tenuis. It is attracted by HIPV and *Tuta absoluta* frass. • *Encarsia formosa* is attracted by HIPV and honeydew. • *Dolichogediivoris longinoda* is attracted by HIPV.
3. Optimizing netting to enhance its effectiveness in terms of microclimate conditions and crop protection.	• Models of micro-climate under netting, pest and beneficial insect population dynamics. • Study of the effectiveness of semio-chemical-treated nets. • Study of the impact of push-pull companion plant arrangements	• Number of models. • List of interesting semio-chemicals for net treatment. • Design of the best push-pull companion plant arrangement for pest management in the field.	• 2 articles have been published: Nordey T, Deletre E, Mlowe N, Martin T. 2020. Nethouses protect cucumber plants from insect pests and increase yields in eastern Africa. The Journal of Horticultural Science and Biotechnology; Nordey T, Deletre E, Mlowe N, Martin T. 2020. Small mesh nets protect tomato plants from insect pests and increase yields in eastern Africa. The Journal of Horticultural Science and Biotechnology.	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
	for pest management in the field.			
4. Environmental economic and social assessment of the crop protection strategy.	• Cost-benefit analysis of the system. • LCA of the farming system. • Socio-technical analysis of the tomato production in Kenya to facilitate the scaling up of this new agroecological tomato farming system.	• CBA of at least 10 farms. • LCA of at least the 4 modalities in the experimental station. • STA of at least 100 farms.	• Outputs have been completed with 2 reports generated.	• Farmers knowledge is a technological impediment to adoption of netting technology.
5. Crop rotation program for netting technology with high value crops and indigenous vegetables.	• Crop protection program for African nightshade. • Crop protection program for amaranth. • Communication tools.	• Field trial covering one crop cycle.	• Outputs have been completed with 1 report generated. • Leaflets and a video clip have been produced.	• Biocontrol is as efficient as chemical control, but netting increases production compared to open-field.
Objective: Develop ant-based repellent semio-chemicals as new IPM tools for fruit fly management.				
1. Identification of an ant-based repellent volatile	• Insect rearing program. • Identification of the gland synthetizing the repellent. • Identification of the bioactive compound.	• Number of colonies. • Bioassays. • Number of biological models tested. • Number of bioactive compounds tested.	• A PhD study is ongoing. • The work has been delayed as the chemical ecology lab was not functional for 9 months.	• Ant abdomen gland produces repellent compounds.
2. Assessment of ant-based semio-chemicals on parasitoids.	• Assessment of negative impact of repellent semio-chemicals on parasitoids. • Combination of repellent semio-chemicals with parasitoids in IPM program.	• Bioassays. • Number of biological models tested.	No progress as an ant-based repellent volatile has not yet been identified.	
Objective: Dissemination and promotion of mango fruit fly integrated pest management (IPM) technologies by 2020.				
1. Proven fruit fly IPM technologies disseminated and promoted among	• Establish partnerships with NARS, NGOs, private sectors, farmers and farmer groups relevant for the implementation	• At least 5 partnerships established with national institutions and research partners relevant for implementation of fruit fly activities.	• Partnerships have been established with national institutions in both Kenya (KALRO) and Ethiopia (EIAR) as well as with higher education institution (Hawassa University, Ethiopia), private sectors (Kibwezi Agro Ltd and Kenya Biologics, both based in Kenya) and NGOs (ADSE, Kenya).	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
smallholder mango growers.	of the fruit fly management activities. • Assess the fruit fly composition, abundance and damage at selected project action sites. • Evaluate, adapt and validate attractants and biopesticide usage at project action sites. • Conduct community-based dissemination and promotion of IPM technologies.	• The composition and abundance of damaging fruit fly species to mango established in at least 5 project action sites. • At least 2 food attractants and 1 biopesticides identified and adopted for use under local condition at action sites. • IPM package for fruit fly suppression disseminated and promoted to at least 10,000 growers at action sites. • Growers adopt at least 2-3 components of the IPM technologies. • Growers reduce fruit fly infestation by 70%; fruit damage reduced by 15%.	• The composition of fruit flies in the project action sites in Kenya and Ethiopia have been assessed. The dominant fruit fly in all the sites was *Bactrocera dorsalis* followed by *Ceratitis cosyra*. • Two fruit fly food baits (Torula yeast and Fruitfly Mania®) have been evaluated. • The fungal isolate *Metarhizium anisopliae icipe* 69 has been identified as a potent isolate against the target fruit flies species. • 3,151 mango growers were directly reached and trained, making the cumulative number of mango growers directly benefitted from the project implementation to be over 40,000 (target was 10,000). • Among the four IPM package, a majority of mango growers have adopted the use of male lure (methyl eugenol), food bait and orchard sanitation. • Growers that adopted the IPM technologies significantly reduced fruit fly infestation by over 80%.	
2. Efficient fruit fly parasitoids introduced, mass produced and released in the field, and their impact on invasive fruit fly species assessed.	• Process and obtain import permit for introduction of exotic natural enemies into Ethiopia. • Conduct baseline assessment to establish alternative wild and cultivated host fruit species for fruit flies and native natural enemies at the project action sites. • Study trophic interactions between native and exotic natural enemies, pest and selected host fruits. • Large-scale augmentative releases of *F. arisanus* and *D. longicaudata*. • Follow-up on establishment, colonisation/dispersal of released parasitoid species and assessment of their impact on invasive fruit fly populations on cultivated and wild host-plants.	• Import permit for at least one parasitoid species granted by Ethiopian government. • At least 3 baseline assessment studies conducted in the project action sites to establish the host range of at least 2 fruit flies species. • Establish the native natural enemies for two fruit flies in at least 2 project action sites. • At least 2 trophic interaction studies for at least one natural enemy, one pest and one host fruit conducted. • At least one parasitoid colony established in each of the project benchmark sites with at least 250,000 wasps in place for mass releases. • At least 2 augmentative releases of one parasitoid species in the project action sites conducted. • At least one study on establishment and dispersal of one parasitoid species conducted in each project action site.	• Import permit for both *F. arusanus* and *D. longicaudata* were granted and parasitoids were shipped to Ethiopia. • Three baseline studies to assess the host range of native and invasive fruit flies were undertaken. Results indicated that these fruit flies are very polyphagous (especially *B. dorsalis).* • The diversity of native natural enemies was assessed. Result indicated that *Psyttalia cosyrae* is the most recovered parasitoid species, though percent parasitism was quite low (< 5%). • Tritrophic interaction of each of the two parasitoid species against *B. dorsalis* on four host plants was undertaken and showed that the two parasitoids perform differentially in terms of percentage recovered puparia, percentage parasitism and developmental time. • Clean laboratory colonies of the two parasitoid species, *F. arusanus* and *D. longicaudata* were established in Ethiopia and the colony at *icipe*, Nairobi was boosted with annual production of 540,000 and 790,750 for *F. arsanus* and *D. longicaudata*, respectively. • 26,330 and 13,500 wasps of *F. arisanus* and *D. longicaudta* were released at the action site (Machakos, Makueni and Elegeyo Marakwet) in Kenya.	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
		• At least one impact study of one parasitoid species conducted on one cultivated and one wild fruit type in at least two project action sites.	• 20,000 wasps of the two parasitoids (10,000 each) were shipped to Ethiopia for both colony maintenance and release in Arba Minch. Three parasitoid releases (total wasps released= 5,962) have been conducted in Ethiopia. • A follow-up post-release assessment was undertaken in Kenya and shown that parasitoids have established with percent parasitism of up to 33%.	
3. New cheap female-biased fruit fly attractants and parameters for postharvest treatment developed, and scientific mechanisms underpinning biopesticide efficacy resolved.	• Develop blends and formulations of new female-biased attractants from compounds of host fruit volatiles. • Identification of host marking pheromones. • Field testing and optimisation of host fruit odours and host marking pheromones for fruit fly monitoring, mass trapping and suppression. • Development of food baits from yeast-based products and field testing for monitoring and suppression. • Assess defensive interactions between facultative endosymbionts and fruit fly biopesticide. • Establish and disseminate parameters for postharvest treatment based on hot water treatment of mango against fruit flies.	• At least two formulations of female-biased attractants from host fruit volatiles developed. • At least two host marking pheromones identified. • At least one attractant field-tested and optimised for fruit fly monitoring and suppression in at least two project action sites. • At least one host marking pheromone field-tested and optimised for monitoring and suppression in at least two project action sites. • At least one yeast-based food baits developed and field-tested at the project action sites. • Endosymbionts screened and characterised in at least one fruit fly species; defensive interactions between facultative endosymbionts and the most potent fruit fly biopesticide established. • Postharvest treatments based on hot water treatment established for at least three mango export cultivars.	• Compound extracts from tropical almond (*Terminalia catappa*), *Marula* and *Sclerocarya birrea* have been found to be attractive to *B. dorsalis* and *C. cosyrae*, with potential of development as female attractants. • The identified host marking pheromones (glutathione, glutamic acid, derivative glutathione oxidised) were evaluated under field conditions. Glutathione had over 90% reduction of mango infestation by *Ceratitis* species in mango-treated orchards compared to the control ones. • Fruitfly Mania® has been evaluated and used for fruit fly suppression. The product has been commercialised by the private sector, Kenya Biologics Ltd. • Activities related to screening and characterisation of endosymbionts have been completed and were reported in 2018. • Postharvest hot water disinfestation treatment parameters against *B. dorsalis* have been developed for two mango varieties, Apple and Tommy Atkins.	
4. Socio-economic impact of the introduced fruit fly IPM and classical biological control technologies assessed.	• Develop baseline of knowledge, attitudes and practices (KAP) related to mango production and IPM technologies using complementary methods including focus group discussions and household	• Baseline on KAP related to mango production and IPM technologies developed in at least two project action sites. • At least one ex-ante study undertaken in at least two project action sites; income of growers increased by at least 20% in at least two project action sites; mango rejection reduced by at least 25% in at	• One working paper produced and submitted for peer review (Farmers' knowledge and perceptions on fruit flies and willingness to pay for a fruit fly integrated pest management strategy in Gamo Gofa Zone, Ethiopia. International Journal of Agricultural Sustainability). • One working paper presented at the 6th African Conference of Agricultural Economists in Abuja, Nigeria, 23-26 September 2019, and submitted for peer review (Adoption of integrated pest management strategy for suppression of mango fruit flies	• Despite limited knowledge of the IPM technologies, the majority of the mango growers are willing to buy the fruit fly package to reduce their produce losses and increase their income. • Enhanced awareness/ exposure can accelerate adoption of the IPM technologies among horticultural farmers in East Africa (using a case of Kenya and Ethiopia).

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
	surveys with data disaggregated by sex and age. • Undertake an ex-ante impact assessment to assess economic impact of IPM implementation. • Conduct a follow-up ex-post impact assessment of IPM upscaling on smallholder farms with data disaggregated by sex and age.	least two project action sites; reduction of insecticide use by at least 30% in at least two project action sites. • At least one ex-post impact assessment study undertaken in at least two project action sites; income of growers increased by at least 20% in at least two project action sites; mango rejection reduced by at least 25% in at least two project action sites; reduction of insecticide use by at least 30% in at least two project action sites.	in East Africa: an ex-ante and ex-post analysis in Ethiopia and Kenya, Agribusiness Journal). • Farmers interviewed at baseline in Ethiopia revisited to assess the impact of IPM training on knowledge and perception of IPM products, demand for the products, mango yield loss and use of pesticides. • One dissemination workshop conducted in Elegeyo Marakwet to present to farmers, extension officers and private sector, the socio-economic findings from two previously conducted surveys. • A third follow-up survey on conducted in Elegeyo Marakwet. • A draft manuscript has been produced from the RCT study in Elegeyo Marakwet.	• Field observations indicated that farmers' knowledge and perception towards fruit fly IPM improved since baseline. Positive benefits such as reduced mango losses due to the pest were reported. Subsequently, farmers were more willingness to pay for the IPM products. • Farmers reported increased mango yields, better quality fruits that were more preferred by buyers and that attracted a premium price after using the fruit fly traps, food bait and practicing orchard sanitation. They however noted accessibility of the products as a challenge. • The survey was conducted to develop a panel dataset (RCT study) to assess the impact of training and use of fruit fly IPM. • Mango farmers who received fruit fly IPM training and materials had significantly lower mango losses due to the pest compared to those who received training only and control group. They were also more likely to demand for fruit fly IPM products compared to the control group.
5. Capacity of NARS and other partners in the transfer of fruit fly IPM and classical biological control technologies strengthened.	• Train NARS (training of trainers) on preharvest management packages. • Conduct farmer field school (FFS)/IPM technology learning hands-on training. • Carry out public awareness to facilitate large-scale adoption. • Advanced level training.	• At least 40 agricultural personnel and extension/ quarantine officers identified and recruited for project implementation • At least three ToT workshops for training of NARS conducted in the project action sites • At least 40 agricultural personnel and extension/ quarantine officers trained on preharvest management packages in each project action site. • At least one model farmer identified in each project action sites • At least one IPM learning site identified and used for dissemination of the fruit fly IPM package in each project action site • At least 6 farmer field days conducted in the project action sites.	• 43 extension officers were trained and 50 CESP (community service providers) were trained. • 6 ToT workshops were held during which the extension officers and CESP were trained on fruit fly IPM. • 7 farmer field days were held at the project action sites. • Training material, detailing the various components of fruit fly management (6,000 fliers) were produced and distributed to the beneficiaries (extension officers, CESP and mango growers). • For improving visibility, 100 branded T-shirts were produced and distributed. • One video highlighting the problem posed by fruit flies and the IPM approach to their management was recorded. • 3 PhD students and 2 MSc students have been trained on various aspects of fruit flies management. One had already graduated.	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
		• At least 60,000 fruit fly training materials (manuals, flyers, posters) distributed to NARS and growers in the project action sites • At least one awareness campaigns conducted through different media (e.g. on local radio stations, TV, farmers' magazines, etc.) • At least one farmers' listening group formed in each project action site • At least 200 CD recorded/ magazines on awareness campaigns distributed to farmers' listening groups. • At least two PhD students trained in the project lifespan on fruit flies and management.		
Objective: Alien invasive fruit flies in Southern Africa: implementation of a sustainable IPM programme to combat their menaces.				
1. Sustainability of the mango production for food and nutrition security through the adaptation, dissemination and scale up of proven fruit fly IPM technologies enhanced.	• Enhanced Mango yield. • 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 2019. • At least one working paper on landscape level land use and land cover characterisation 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.	• 42 demonstration and learning sites established; 19 are female-headed and 23 are male-headed.	
2. The role of biocontrol agents (*F. arisanus* and *D. longicaudata*) in suppression of the alien invasive *Bactrocera dorsalis* enhanced.	• Institutional and personnel capacity on application of biological enhanced. • Native and invasive fruit flies significantly supressed. • National laboratories for parasitoid rearing upgraded.	• Mass rearing of introduced parasitoids by 2019. • Upgrading national laboratories for parasitoid rearing by 2020. • Obtain import permit for the introduction and releases of parasitoids in the target countries by 2019.	• Laboratory colonies of the two parasitoids have been boasted with an annual production of 800,000 and 550,000 wasps for *F. arisanus* and *D. longicaudata*, respectively. • Import permits for the two parasitoid species have been obtained for Mozambique and Zimbabwe.	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
		• Introduction and large-scale augmentative releases of *F. arisanus* and *D. longicaudata* by 2020. • Assessment of establishment, colonisation/ dispersal of released parasitoid species, and assessment of their effectiveness on *B. dorsalis* populations by 2022.		
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 flies IPM interventions in the mango production and value chain elucidated and documented.	• At least one ex-ante study undertaken by 2019. • At least 100 researchers, policymakers, farmers, extension officers and donors who are aware and who recognise the economic, social, environmental and human health impacts of interventions by 2022. • The socio-economic and gender impact of the IPM interventions in the mango production and value chain assessed by 2020. • Barriers and success factors for promoting, scaling up IPM technologies and increasing women and youth participation in the mango value chain understood by 2020. • Cost-benefit analysis of the existing management practices and the proposed IPM technologies conducted by 2022.	• One ex-ante study has been undertaken in Malawi, Zambia and Zimbabwe and data analysis is in progress.	
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	• 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 about IPM fruit fly management by 2022. • 20,000 extension training materials produced by 2022. • One million resource-poor farmers and policy makers are aware of fruit fly IPM by 2022.	• 2 ToT workshops were held (one in Zambia and one in Zimbabwe) during which a total of 54 (54% female) extension officers were trained on fruit fly IPM. • 5 farmer field days were held (2 in Zambia and 3 in Zimbabwe) which were attended by a total of 279 (57% female) mango growers. • 2 Ph.D students have been recruited.	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
	information sharing, and market linkages strengthened.	• Three post graduate scholars graduated by 2022.		
Objective: Upscaling and institutionalizing of fruit fly IPM technology among smallholder fruit growers in East Africa by 2021.				
1. To establish the baseline damage caused by different fruit fly species on mangoes and intensify dissemination of fruit fly IPM approaches in the new project action sites in Kenya, Ethiopia and Tanzania.	• Regular and systematic fruit sampling of mango in the new target locations to ascertain 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 (*F. arisanus* and *D. longicaudata*) at *icipe* for introduction and mass releases in the project benchmark sites.	• Quantification of damage and composition of fruit flies. • 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, Tanzania. • 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.	• Out of 9 fruit fly species identified, the invasive fruit fly species *B. dorsalis* and one native species *C. cosyra* were the most dominant fruit fly species inflicting severe damage on fruits and vegetables in the three countries. • The damage levels recorded were 58.46% in Ethiopia, 65.2% in Kenya and 85.8% in Zanzibar (Tanzania). • Four native parasitoids have been identified in Kenya, Ethiopia and Tanzania with extremely low parasitism rates (>0.5%). • In Zanzibar, despite the incubation of huge consignment of fruits and vegetables from the field, no native parasitoid species have been recorded. • A total of 3 demonstration sites have been established in Zanzibar. • An additional 5 learning sites have been established in Kenya (2 in Makueni) and Ethiopia (3 Arba Minch). • Three demonstration activities were conducted (2 in Kenya and 1 in Zanzibar). • 3 mass parasitoid field releases carried out in Ethiopia at Arba Minch (5,962 wasps released). • 1 major release of parasitoids has been conducted in Makueni, Kenya (4,500 wasps of each species).	• The fruit fly problem is intensive in Zanzibar, with *B. dorsalis* being the dominant pest on mango. Trap catches of the pest has been very high. Intensive IPM technologies dissemination, application and adoption must be propagated in Zanzibar.
2. To develop capacity on IPM and good agricultural practices for NARS and	• ToT workshop on fruit fly biological control and IPM technologies conducted for extension officers and	• Number of NARS and CESPs trained. • Number of training materials handed out. • Number of awareness campaigns. • Number of growers reached.	• A total of 131 extension officers and model farmers have received detailed training on fruit fly IPM technologies and good agricultural practices along the value chain in Kenya (Makueni) and Tanzania (Zanzibar).	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
growers to support up-scaling of fruit fly IPM technologies in the project target countries.	community extension service providers in the project benchmark sites. • Awareness campaigns and sensitisation 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 at *icipe* carried out for NARS partners on natural enemy production, releases and assessment of impact.	• Number of NARs trained on parasitoid rearing.	• 2 awareness campaigns have been organised to train farmers (15) and extension officers (30). • 335 growers (264 males and 71 females) have been trained and received fruit fly IPM starter kits.	
3. To create linkages and partnerships for enhanced transfer and upscaling of fruit fly IPM technologies and strengthening of the mango value chain in Kenya, Ethiopia and Tanzania.	• Approval by county governments to open outlets to supply fruit fly IPM technologies at the grassroot level for growers' accessibility. • Database of mango growers in the project countries created. • Linkages between suppliers and growers/growers' association have been 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 mobilisation at local and regional levels to enable them undertake field testing	• Numbers of stakeholder meetings taken place. • Number of approvals by county governments. • 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 mobilisation for IPM technologies sustainability.	• 2 workshops were organised to train extension officers and mango growers. • A visit was organised for the Zanzibar Plant Protection Department with the private sector partners Real IPM, Kenya Biologics and Farmtrack Consulting Ltd. • Project partners from Tanzania also visited *icipe* for discussions on future IPM activities in the country and discussions on linkages with the IPM suppliers were undertaken. • Database of fruits and vegetable growers in Kenya has been developed. • In the database, some Kenyan growers have been linked to private sector partners. • One interactive mobile-SMS-based system has been launched in collaboration with the Bio-vision Africa Trust. • Five workshops have been organised already in Kenya, Ethiopia and Tanzania (Zanzibar) to educate growers on the opportunities to form committees and to engage their respective governments for financial assistance to support their farming activities.	• SMS system that was launched in collaboration with Biovision Africa Trust has boosted the IPM dissemination activities.

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
	and continued sharing of the fruit fly IPM technologies in the communities.			
Objective: Develop IPM tools and strategies for major coffee pests in East Africa based on a better knowledge of their bioecology by 2020				
1. Thermal requirements characterisation for major coffee pests in East Africa.	• Thermal thresholds determined for *Hypothenemus hampei*, *Monochamus leuconotus* and *Antestiopsis thunbergii* through life table study at constant temperatures and phenological modelling.	• 3 publications. • Thermal requirements of 3 major pests of coffee in East Africa. • Set of models available for further demographic simulations for 3 major pests of coffee.	• The thermal thresholds had been acquired for the 3 major pests targeted. • For *Hypothenemus hampei,* from litterature (Jaramillo et al. 2009) and from a lab experiment conducted by a local PhD student which led to a publication (Azrag et al. 2020. Temperature-dependent development and survival of immature stages of the coffee berry borer *Hypothenemus hampei* (Coleoptera: Curculionidae)). • For *Monochamus leuconotus*, from another lab experiment conducted by the same local PhD student which led to a publication (Azrag et al. 2020. Modelling the effect of temperature on the biology and demographic parameters of the African coffee white stem borer, *Monochamus leuconotus* (Pascoe)(Coleoptera: Cerambycidae)). • For *Antestiopsis thunbergii,* still from previous work of the same student (Azrag et al. 2017. Temperature-dependent models of development and survival of an insect pest of African tropical highlands, the coffee antestia bug **Antestiopsis thunbergii** (Hemiptera: Pentatomidae)). • Different models were used for each insect but also for the different life stages. We obtained 3 distinct set of models able to predict phenology of these insects.	• It has been possible to model separately each life stage of each insect. However, it is difficult to have a homogeneous set of models for a more generic approach for all insects. Most of our efforts are oriented toward this goal now.
2. Distribution mapping for major coffee pests in East Africa, in the current climate situation and in different scenarios of climate warming.	• Demographic parameters simulated from phenological models for *Hypothenemus hampei*, *Monochamus leuconotus* and *Antestiopsis thunbergii.* • A set of risk maps for the 3 pests on coffee in the current climatic situation and in different scenarios of climate warming.	• Sets of risk maps published in scientific journals. • Sets of risk maps available as a component of an IPM program for major coffee pests, targeting stakeholders of the coffee industry.	• This work had been done for *Hypothemus hampei* (Jaramillo et al. 2011) • As part of the PhD of Abdelmutalab Azrag (defended in 2019), it had been done for *Antestiopsis thunbergii* (Azrag et al. 2018. Prediction of insect pest distribution as influenced by elevation: combining field observations and temperature-dependent development models for the coffee stink bug, **Antestiopsis thunbergii** (Gmelin)).	• It is not easy to connect phenological models with maps especially for future climate change scenarios. The need for data from the field in order to validate projections has been underestimated. • A more comprehensive approach is under development for *Monochamus leuconotus*.
3. Characterisation of major coffee pest population dynamics in coffee farms and of	• Networks of smallholding coffee farms implemented for observation in different locations.	• Data sets available for modelling work. • Models describing the impact of agroecological factors on major coffee	• Networks of smallholder coffee farms for observation in different locations were supposed to be implemented during the project. However, these networks did get implemented, which prevented data collection.	• To understand population dynamics at different scales, maps produced by remote sensing appeared to be a key step of the work. A lot of efforts during 2019 had been

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
agroecological factors impacting the dynamics.	• Data sets for monthly monitoring of *Hypothenemus hampei*, *Monochamus leuconotus* and *Antestiopsis thunbergii* populations and damage in different locations of East Africa. • Main agroecological factors characterised for coffee farms, including microclimate, shade, coffee fruiting cycle, farmer practices. • Models describing the impact of main agroecological factors on major coffee pest dynamics. • IPM recommendations developed based on these models.	pest dynamics published in scientific journals. • Sets of IPM recommendations for shade management and other best practices available for major coffee pests, targeting stakeholders of coffee industry.	• Some progress had been made through the PhD student Gladys Mosomtai. A map of coffee agrosystems in Murang'a county based on several sources of satellite images has been produced. This work has been presented in conferences and is about to be published. A collection of landscape metrics and environmental factors such as local temperature and humidity have been collected. We are working on the modelling of the relationship between these environmental factors and the coffee pest dynamics.	invested in this aspect. Gladys Mosomtai developed skills in machine learning and remote sensing for this purpose.
4. Identification and utilisation of semio-chemicals in the management of *Antestiopsis thunbergii*.	• Promising bioactive volatiles isolated from coffee berries or conspecifics.	• A set of bioactive compounds available for field assessment. • 1 publication for promising kairomones for the control of *A. thunbergii.* • 1 publication for promising pheromones for the control of *A. thunbergii*.	• Work was performed during the PhD of Teresiah Njihia (Development of semiochemical-based strategies for the management of Antestia bug, *Antestiopsis thunbergii* (Heteroptera: Pentatomidae)), who defended in 2019. • A paper about pheromones of *Antestiopsis thunbergii* is in preparation.	
Objective: Promote adoption of push-pull technology for effective management of striga, stemborers, fall armyworms infestation and aflatoxin contamination of cereals through collaboration with international and national partners by 2020.				
1. Push-pull technology implemented by over 120,000 farm households, and indirectly benefit over 720,000 people in East Africa.	• Food sufficiency and household incomes of 120,000 push-pull farmers increased by at least 50% by 2019 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 optimised and employed. • Cereal and fodder yields and milk production levels among target farmers. • Number of partnerships formed.	• Target surpassed: push-pull adopted and planted by 241,040 (133,465 female, 107.575 male) farmers in Eastern and Central Africa by end of 2019. Among these, 155,123 farmers (84,652 females and 70,471 males) had cumulatively adopted the climate-smart push-pull technology by end of 2019. This translates to about 720,000 indirect beneficiaries having improved food sufficiency, nutrition and incomes. • More than 241,000 farm households experienced more than double increase in cereal crop yields (61.9% increase in maize yields), 5 times more fodder production, and increase in milk production (from 263 L/year/household to 460 L/year/household) and incomes (aggregate economic surplus > USD 73 million in Kenya). • Large-scale dissemination of climate-smart push-pull undertaken directly and through partnerships, group trainings,	• The multiple benefits conferred by push-pull in controlling stemborers, fall armyworm, Striga weeds and mycotoxin contamination in addition to improving soil fertility and generating fodder makes the technology as one of the most viable intensification strategies in smallholder African agriculture. • Recent discovery of the effectiveness of push-pull against fall armyworm continues to drive push-pull adoptions in sub-Saharan Africa, and likely to introduce new demand for push-pull beyond Africa. • The technology's integration of cereal and livestock production tremendously increase demand of push-pull as a multi-functional

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
		• Number of stakeholders trained.	*icipe* and partner extension staff, farmer teachers, field days, audio-visual methods, social media and illustrated materials like cartoon books, exchange visits and agricultural shows. Secondary reach through partners, social media and mass media created awareness of 21.5 million people in 18 sub-Saharan African countries. • More than 30 partnerships established for adaptation, validation and scaling up of climate-smart push-pull in 18 sub-Saharan countries: Kenya, Uganda, Tanzania, Ethiopia, Zimbabwe, Malawi, Zambia, Rwanda, Burundi, Burkina Faso, Congo, Mozambique, Togo, Benin, Cameroon, Senegal, Ghana and Mali.	technology. Farmers in Africa traditionally practice mixed agriculture. • Promoting the uptake of the technology require a combination of technology transfer pathways that are sustainable in the long term based on local networks and social capital and working across the entire innovation ecosystem continuum. • Building strong partnerships with the farming communities, national extension networks, NGOs, and the private sector players remains key in scaling up push-pull technology. Their involvement also enhances impacts of the technology on beneficiary livelihoods.
2. An integrated management approach for Napier stunt disease.	• Improved incomes and livelihoods of at least 5000 Napier farmers in Western Kenya by at least 50% through adoption of an integrated Napier stunt disease management strategy, characterised by increased fodder and milk production by 2019.	• Quantity of Napier grass and milk produced. • Number of alternative fodder grasses in use. • Number of farmers using the integrated disease management approach. • Number of partnerships formed. • Number of stakeholders trained on integrated disease management. • Number of peer-reviewed publications.	• More than 13,300 Napier stunt disease-resistant planting canes (Ouma2, South Africa and three additional stable cultivars Phanice, Wanga and Tundwe) have been distributed to farmers in western Kenya. • 12 alternative fodder grass germplasm, including 3 *Brachiaria* accessions showed no infection by the Napier stunt disease pathogen. The grasses are being multiplied by farmer groups. • 9,097 (5,586 female and 3511 male) smallholder farmers are using Napier stunt disease-resistant Napier grass cultivars by 2019. The farmers have been trained on disease management and supported to establish bulking sites for disease-resistant Napier grass cultivars in Western Kenya. Additionally, 3,538 extension agents trained. • Further fodder commercialisation surveys conducted in Western Kenya identified potential commercial value chain players in the region including 130 traders, 349 consumers and 125 producers that will help drive this result area.	• Integrated management of Napier stunt disease involves several approached and additional research on (1) the effects of plant nutrition on disease progression, (2) screening additional Napier grass materials and alternative fodder grasses from farmers, (3) understanding the distribution of phytoplasma on different parts of Napier grass, (4) back transmission of the Napier stunt disease-causing bacteria phytoplasma by the pathogen vector, *Maiestas banda*, and (5) effects of phytoplasma on vector development. • On-farm research shows that most of the selected Napier stunt disease -tolerant cultivars have so far remained stable for >2 years on farmers' fields and have not been infected by new strains of stunt phytoplasma in the multiplication sites in continuous post-exposure tests.
3. Stemborer and fall armyworm management approach developed by exploiting early	• Staple food sufficiency achieved by at least 20,000 farmers in Western Kenya by 2020 though grain yield increases by 30%.	• Number of 'smart' maize varieties with early herbivory traits identified. • Number of farmers adopting the use of 'smart' maize varieties.	• Studies to establish the potential role such plants can play in improving stemborer control efficiency of push-pull were continued. Indirect defence abilities of 6 'smart maize' cultivars (locally-adapted landraces, improved breeding lines and commercial varieties) to stemborer (*Chilo partellus*) pest	• Smart defence traits identified in cereal lines and in some of the African grasses can be exploited to enhance effectiveness of the technology in managing stemborer pests. Findings suggest that the VOCs released by

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
herbivory traits and plant signaling	• Novel scientific knowledge on early herbivory and plant signalling generated and applied in crop protection by scientists, extension agents and policy makers by 2020.	• Increase in grain yields. • 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 fall armyworm control by exploiting inherent plant defence traits.	egg disposition and parasitism levels were further investigated. Indirect defence is mediated herbivore induced plant volatiles (HIPVs), whose production is triggered by feeding damage or earlier stage of insect attack. Chemical and electrophysiological analyses revealed strong induction of bioactive compounds from maize landraces exposed to molasses grass volatiles. • Attraction of parasitic wasps, *Cotesia sesamiae*, to odours of plants exposed to *C. partellus* eggs and pest parasitism levels were again measured on the selected lines. • Phenotypic and genotypic data were combined in a genome wide association study (GWAS) in order to identify single-nucleotide polymorphisms (SNPs) strongly associated with the egg induced indirect defence trait. • Soil-mediated effects of functional biodiversity were investigated in push-pull on maize plant growth, and resistance against insect herbivores. Maize plants grown in soil conditioned by push-pull companion cropping had a higher growth rate compared to those grown in soil from non-push-pull monoculture fields. In addition, soil from push-pull fields induced a constitutively higher and qualitatively different emission of volatile organic compounds than soil from non-push-pull fields. Moreover, secondary defense metabolites such as 2,4-dihydroxy-7-methoxy-2H-1,4-benzoxazin-3(4H)-one (DIMBOA), were produced in larger quantities in plants grown in soil from push-pull fields compared to those from monoculture fields. • Two papers were published on: (1) molasses grass induction of direct and indirect defense responses in neighbouring maize plants (Tolosa et al. 2019. Journal of Chemical Ecology 45, 982-992) and (2) plant-soil feedbacks of maize companion cropping in push-pull increasing chemical plant defenses against herbivores (Mutyambai et al. 2019. Frontiers in Ecology and Evolution 7, 217).	molasses grass can induce direct defence responses in neighboring maize landraces, while maize hybrids lack the ability to respond to molasses grass VOCs. Plants activating defences by VOC exposure alone could realise enhanced levels of resistance and fitness compared to those that launch defence responses upon herbivore attack. • Studies demonstrate the potential of plant signaling as a component of management approaches for stemborer pests. Soil-mediated alterations in plant secondary metabolism were associated with reduced herbivory by larvae of the stemboring pest *Chilo partelllus*. This provides novel evidence that plant-soil feedbacks can affect plant metabolism, growth and resistance to pests.
4. Fall armyworm management approach developed by understanding the mechanism by which push-pull controls the pest by 2020.	• Scientific knowledge generated and included in integrated management of fall armyworm in Africa by scientists, extension agents and policy makers by 2020.	• Percentage change in fall armyworm infestation in push-pull cereal fields. • Number of farmers adopting the use of push-pull integrated fall armyworm management approaches. • Number of peer-reviewed publications on integrated management of fall armyworm using push-pull technology.	• The functionality of the climate-adapted push-pull was further evaluated on-farm for the management of fall armyworm. Field observation, both biophysical and socio-economic data, were collected on fall armyworm distribution and intensity of infestation. • The chemistry of push-pull companion plants and the underlying control mechanisms as well as farmers' experience with push-pull vis-à-vis fall armyworm were further	• Reductions of 82.7% in average number of fall armyworm larvae per plant and 86.7% in plant damage per plot were observed in climate-adapted push-pull compared to maize monocrop plots. • Preliminary studies show that SOS chemicals e.g. nonatrine,(E)-ß-ocimene, α-terpinolene, β-caryophyllene and humulene

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
		• Number of stakeholders trained on FAW control by using the Push-pull strategy.	investigated. There was no significant difference in fall armyworm infestation between climate-smart and conventional push-pull. However, severity of infestation was lowest in climate-smart push-pull, and the differences were highly significant compared with maize intercropped with leguminous crops and mono-cropped maize. Infestation of maize by fall armyworm in push-pull fields was lower, compared with maize intercropped with bean, soybean and groundnut. • The severity of infestation was highest on mono-cropped maize compared with all the treatments. These results provide tangible proof that push-pull technology can significantly reduce the fall armyworm infestation in maize. • 33,992 (20,417 females, 13,575 males) farmers adopted push-pull integrated fall armyworm management approaches. • Over 350 stakeholders were trained on fall armyworm control using the push-pull strategy. • A paper was published on additional agro-ecological options for management of fall armyworm and other invasive pests (Rhett et al. 2019. Journal of Environmental Management 243, 318-330).	produced by *Desmodium* repel ovipositing fall armyworm females. Infestation symptoms in climate-smart and conventional push-pull technology systems were 36% and 38%, respectively, compared with maize mono-crop, where 95% infestation was recorded. • Similarly, maize grain yields were significantly higher, 2.7 times, in the climate-adapted push-pull plots. These results demonstrate that the technology is effective in controlling fall armyworm with concomitant maize grain yield increases and represent the first documentation of a technology that can be immediately deployed for management of the pest. Agro-ecological approaches offer culturally appropriate low-cost pest control strategies that can be readily integrated into existing efforts to improve smallholder incomes and resilience through sustainable intensification. Such approaches should therefore be promoted as a core component of IPM programmes for fall armyworm in combination with crop breeding for pest resistance, classical biological control and selective use of safe pesticides
5. An integrated management approach developed and implemented for *Striga* control in maize in Western and Southern Africa.	• Food sufficiency and livelihoods of at least 30,000 smallholder farmers improved by at least 50% by 2018 through efficient control of *Striga* resulting in increases in maize yields by at least 50%.	• 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.	• All the 33,992 (20,417 females, 13,575 males) farmers who adopted push-pull in 2019 integrated *Striga* control methods, and reduced *Striga* infestation 18-fold, increasing acreage by 40,790 acres under integrated *Striga* control methods. Concomitantly grain yields increased 2.7 times. • Comparative studies further evaluated the performance of *Desmodium* species of African origin. Results revealed that *Desmodium incanum* and *Desmodium ramosissimum* are the best candidates for a push plant due to their high drought-tolerance, biomass yield, and ability to flower and produce seeds across various agro-ecological environments. They were equally effective against *Striga* weeds and for carbon sequestration. • On-station studies on climate change mitigation through improved soil health examined the growth performance of	• In long term crop production, intercropping *Desmodium* with maize provides higher maize grain yields than maize intercropped with common beans, cowpea, crotalaria, groundnut, green gram and monocrop maize. Observed differences in yield were large enough to compensate for food legumes otherwise produced in maize-food legume intercrops. • Elucidating the biosynthesis of C-glycosylflavones (CGFs) found in drought-tolerant *Desmodium incanum* and *Desmodium ramossisimum* has potential to unearth opportunities for transferring the enzymic and genetic basis for the *Striga*

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
			different legume intercrops, carbon sequestration and nitrogen fixation. Maize under push-pull was compared with maize intercropped with common bean, crotalaria, groundnut, cowpea and green gram, and maize monocropping as the control. Maize grown with *Desmodium* in push-pull technology had better growth, grain and stover yields by more than three times that of the other treatments. • Nitrogen, ammonium and available phosphorous were highest in push-pull systems compared to other maize-legume intercrops and maize monocrop, resulting in higher maize grain yields in the push-pull plots. • A comparative analysis of PlanetScope and Sentinel-2 space-borne sensors in mapping *Striga* weed evaluated spatially explicit innovative geospatial technologies that can deliver timely detection of weeds within agro-ecological systems. The study evaluated the strength of Sentinel-2 satellite with the constellation of Dove nanosatellites in Kenya. Comparatively, Sentinel-2 demonstrated slightly lower *Striga* detection capacity than PlanetScope, with an overall accuracy of 88% and 92%, respectively. • A paper was published on comparative analysis of PlanetScope and Sentinel-2 space-borne sensors in mapping *Striga* weed (Mudereri et al. 2019. Journal of Environmental Management 243, 318-330).	inhibiting allelopathic trait to cereals and food legumes. • Comparisons of spatially explicit geospatial technologies demonstrate that Sentinel-2 data has the capability to provide spatial explicit near real-time field level *Striga* detection which was previously difficult with broadband multispectral sensors.
6. Food and nutrition safety improved by controlling mycotoxin contamination in maize through push-pull technology by 2020.	• At least 10,000 farmers in western Kenya reduce aflatoxin and other mycotoxin contaminations of maize crop harvests by 30% by 2020.	• Number of farm households with reduced aflatoxin contamination in maize grown in push-pull farms.	• 6,900 farmers monitored effective control of aflatoxin in their push-pull farms, where aflatoxin contamination levels reduced to 7.3% of the maize crop in push-pull compared to maize monocrop (20.8%). • 116 push-pull and 139 non-push-pull farmers were also surveyed to determine the socio-economic and agronomic factors that influence farmers' knowledge on incidence and contamination of maize by ear rots and associated mycotoxins in Western Kenya. Overall, less than 20% of maize samples were contaminated with both aflatoxin and fumonisin, and more maize samples were contaminated with fumonisin as compared to aflatoxin. • Maize samples from push-pull cropping system had lower levels of fumonisin, less than the Kenyan regulatory threshold (10 µg/kg) for aflatoxin and European Commission regulatory threshold (1,000 µg/kg). Significantly less push-pull (8%) maize was contaminated with aflatoxin compared to non-push-pull (12%). All the push-pull maize was safe for	• Only a small proportion of farmers have knowledge of aflatoxin and ear rots in maize. These results imply that creating awareness is key to mitigation of ear rots and mycotoxin contamination of maize. The results also suggest that the levels of aflatoxin and fumonisin in maize in Western Kenya were influenced both by pre-harvest agronomic practices and by the cropping system adopted, push-pull or not.

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
			consumption while 4.3% of non-push-pull maize was contaminated with high aflatoxin levels (above 10 ppb). Fumonisin contamination of maize was reduced by 46% under push-pull. • Levels of both aflatoxin and fumonisin were significantly and positively associated with stemborers and fall armyworm damage. • A paper was published on influence of socio-economic and agronomic factors on aflatoxin and fumonisin contamination of maize in western Kenya (Njeru et al.2019. Food Science & Nutrition 7, 2291-2301).	
Objective: Baseline information of plants - Lepidoptera stemborers – parasitoids interactions by 2020.				
1. Baseline information on host plant selection mechanisms by Lepidoptera stem borers (Noctuidae) and refugia of lepidopteran maize stemborers and associated parasitoids during non-cropping season.	• Description of herbivore- plant volatiles induction on oviposition within a community of maize Lepidoptera stem borers. • Study on the importance maize residues to ensure the carry-over of maize stemborers and their associated parasitoids during the non-cropping season as compared to surrounding wild habitat.	• Conspecific or heterospecific larvae-infested maize plants produce specific chemical signatures that female moths use as host cues. • Description of the importance of maize residues as compared to wild habitat to ensure the carry-over of maize stemborers and their associated parasitoids. This is valid in regions where the wild habitat is reduced.	• Bioassays (Y-tube experiments) and volatiles analyses by GC-MS achieved. • Field surveys in maize field in Makutano and Murang'a achieved. • Parasitoids releases of *Cotesia flavipes* in Makutano and *Cotesia sesamiae* in Murang'a for the follow up on the importance of maize residues as compared to wild habitat to ensure the carry-over of maize stemborers and these parasitoids species.	• Females of *Busseola fusca*, *Sesamia calamistis* and *Chilo partellus* oriented significantly towards VOCs emitted by both conspecific and heterospecific infested plants as compared to uninfested plants (both laboratory and field observations validated this result).
2. Impact of fall armyworm invasion on maize stemborers' communities and their associated parasitoids in maize field in a context of climate change (part of the FAW EU Project).	• Study on the effect of temperature on interactions between a community of lepidopteran maize stemborers and the fall armyworm under laboratory conditions. • Study on the effect of larval density and duration on the competition outcomes between lepidopteran maize stemborers community and the fall armyworm under laboratory conditions. • Study on the Influence of the recent introduction of the fall armyworm, Spodoptera frugiperda (Lepidoptera:	• Identification of the type of intraspecific interaction that characterises fall armyworm larvae resource utilisation and their interspecific interactions with maize stemborers communities including *B. fusca, S. calamistis* and *C. partellus*, and information on the effect of temperature on these interactions under laboratory conditions. • Evidence that the introduction of *Spodoptera frugiperda* had changed the equilibrium of maize stemborer communities and showed to be able to co-habit with stemborer species as additional pest in maize fields across the cropping seasons in different agro-ecosystems.	• Laboratory experiments done to study the interactions of *S. frugiperda* and stemborers larvae according to the temperature, the larval density and the duration of the interactions. • Extensive surveys conducted at different maize agro-ecosystems in Kenya where the stemborers used to co-occur on maize and at the same maize fields before and after the fall armyworm had invaded Kenya. • *Spodoptera frugiperda* larvae acceptance tests by *Cotesia* species for parasitisms done.	• *Spodoptera frugiperda* invaded the maize fields surveyed by our team since the last 10 years. This obliged us to undergo a study on the interactions of this new invasive species with the already indigenous Lepidoptera maize stem borers.

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
	Noctuidae), on maize stemborers and their associated parasitoids composition in maize fields in Kenya. • Study on host acceptance by the stemborer's parasitoids, *Cotesia flavipes* and *C. sesamiae* towards *Spodoptera frugiperdae* larvae.	• Identification of the effect of larval density and duration on the competition outcomes between lepidopteran maize stemborers community and fall armyworm. • Confirmation if *C. flavipes* and *C. sesamiae* are able or not to parasitise *S. frugiperda*.		
3. Genome sequencing of *Busseola fusca*.	• To understand the biology of *Busseola fusca*, we sequenced, assembled and annotated the genome and transcriptome of this important maize pest.	• Genome and transcriptome of *B. fusca* sequenced, assembled and annotated. .	• The genome of *Busseola fusca* was sequenced, assembled and annotated. • We identified unique gene families potentially related to metabolism of xenobiotic chemicals, pheromone biosynthesis and immune response towards parasitism. • Still remaining is the transcriptome analysis.	• Important to maintain constant international collaborations.
4. Baseline information on host selection mechanisms by *Cotesia* spp. parasitoids (Braconidae) of Lepidoptera stemborers.	• Determination of the candidate genes involved in host acceptance by *Cotesia sesamiae*.	• Genetic studies that involve use of two *Cotesia sesamiae* populations (differing in *B. fusca* acceptance) could be useful in the identification the candidate genes involved in host acceptance by this parasitoid species. This study is geared towards the determination of the candidate genes involved in host acceptance through cross-mating the two C. sesamiae populations in the laboratory to provide a proof for the heritability of host acceptance in the resulting progenies.	• Link of phenotypic characterisation (host acceptance) of the progeny to genotype in a QTL (quantitative trait loci) analysis approach to generate genotypes using a RADseq (restriction site Associated DNA sequencing) strategy is ongoing.	• Sufficient production of both host and parasitoid was crucial and can delay our planned study.
Objective: Integrated pest management strategy to counter the threat of invasive fall armyworm to food security in Eastern Africa (FAW-IPM) by 2022				
1. Establishing an emergency community-based fall armyworm monitoring, forecasting, early warning and management system (CBFAMFEW) in Eastern Africa.	• Community-based fall armyworm monitoring, forecasting and early warning established in target regions of Uganda, Burundi and Rwanda that aid in timely interventions for fall armyworm management. • Enhanced awareness on CBFAMFEW among policy makers, extension agencies and growers in Uganda, Burundi and Rwanda.	• *Number of national/ county/sub-county fall armyworm officers/staff trained as ToT for community training.* • Number of pheromone traps established, and mobile applications downloaded by community focal persons in Uganda, Rwanda and Burundi. • No. of districts, villages covered by the community-based fall armyworm network in Uganda, Rwanda and Burundi.	• In partnership with FAO-SFE and funding from USAID-OFDA, *icipe* co-implemented the community-based fall armyworm monitoring program (CBFAMFEW) to create awareness, strengthen monitoring and foster preparedness. The following activities were conducted. • Community-based fall armyworm monitoring networks were established in 15 districts of Rwanda, Uganda and Burundi. • National training-of-trainers (ToT). • District level stakeholder meeting held (awareness creation). • Training of community focal persons (CFPs) - both women and men a total of 160 individuals in each country. • Field monitoring tools installation and deployment.	• Sustainability of the community-based pest monitoring beyond project life needs to be addressed.

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
			• Season-long monitoring and technical backstopping. • Field days and national workshops.	
2. Regional preparedness, early warning, information on available management options and capacity for timely response to fall armyworm infestation in Eastern Africa enhanced.	• Extension agencies and maize growers in Kenya, Tanzania, Ethiopia, Rwanda and Uganda have access to fall armyworm monitoring and surveillance tools. • Additional effective fall armyworm IPM options available. • Best-bet cultural practices for fall armyworm management promoted.	• At least 100 extension officers per target country have access to monitoring surveillance tools by 2022. • At least 100,000 men and women 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. • By 2020, one additional effective fall armyworm IPM option registered and available for commercialisation. • At least 3 best-bet cultural practices identified and promoted by 2019.	• In partnership with Rothamsted Research, automated fall armyworm pheromone traps were evaluated in over 20 locations in Kenya. • Multi-location trials on efficacy of biopesticides was undertaken in Embu, Mbita, Bukura. Results indicated good efficacy of biopesticides for management of early life stages of fall armyworm. • On-station intercropping trials at *icipe*-Mbita with different legumes showed that intercropping maize with *Desmodium* produced the best results in controlling fall armyworm. • Out of the five components of fall armyworm IPM (monitoring, use of natural enemies, biopesticides, capacity building and cultural management), the project targeted the push-pull technology as one of the best-bet fall armyworm IPM options to be disseminated along with legume intercropping. • Extensive stakeholder engagements with private sector partners and regulatory authorities have resulted in label extension/product registration trials in Kenya and introduction of products in Tanzania and Uganda.	• Trap design and pheromone lures for automated fall armyworm monitoring needs to be optimised. • Biopesticides for fall armyworm management needs to be rapidly scaled along with cropping systems based approach.
3. Knowledge on the biology and ecology of fall armyworm enhanced.	• Enhanced understanding on the biology of fall armyworm in East Africa for development of fall armyworm IPM strategies.	• At least 3 publications highlighting fall armyworm bio-ecology completed by 2021.	• Diversity of fall armyworm strains and the gut endosymbionts deciphered (Gichuhi et al. 2020. PeerJ, e8701). • Temperature and larval dispersal activity were the main factors determining the interaction between fall armyworm and stemborers infesting maize (Sokame et al. 2020. Insects, 11, 73). • Humid regions around the lake region in Eastern Africa were found to be hotspots for the prevalence of fall armyworm throughout the year (Niassy et al. 2020. Under review in PlosONE).	
4. Effective natural enemies for fall armyworm identified, introduced, tested and released in target countries.	• Both indigenous and introduced natural enemies of fall armyworm effectively conserved for natural control of FAW in East Africa.	• At least 1 effective natural enemy released in 3 target countries by 2020. • At least 100,000 parasitoids released per country by 2022.	• The natural association of more than 5 larval parasitoids and 2 egg parasitoids identified. • The *Cotesia* species parasitizing maize stemborers accepted fall armyworm larvae for stinging resulting in non-reproductive fall armyworm mortality. • Field parasitism and laboratory performance of key parasitoids of fall armyworm assessed in three East African countries. • Ecological suitability for the establishment of *C. icipe* established in Africa and globally.	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
			• Stable colonies of at least 4 larval parasitoids and two egg parasitoids established. • Preliminary field releases of *C. icipe* and *T. remus* initiated. • Current efforts are for scaling mass production of *C. icipe* and egg parasitoids.	
5. Novel and environmentally-friendly biocontrol technologies developed, tested and disseminated for fall armyworm management.	• Novel biopesticides and their application strategies available for fall armyworm management in East Africa.	• At least 2 biocontrol technologies developed by 2020. • At least 25,000 growers in 3 target countries directly benefitting from biocontrol technologies by 2022.	• More than 5 effective isolates (ICIPE 7, 78, 40, 20 and 41) of entomopathogenic fungi causing more than 80% mortality of eggs and early instars identified (Akutse et al. 2019, Journal of Applied Entomology 143, 626-634). • Widespread field epizootics of *Metarhizium rileyi* recorded in Kenya (Gichuhi et al. 2020. PeerJ, e8701). • Isolates *M. anisopliae*, ICIPE 7 and *Beauveria bassiana*, ICIPE 621 have been found to be effective against the adult stage of fall armyworm. • Isolates ICIPE 7 and ICIPE 621 were compatible with commercial fall armyworm pheromones Falltrack®. • Potential for the dissemination of entomopathogenic fungi between sexes has been confirmed with laboratory evaluations. • Multilocational field efficacy trials have been established in Kenya (Embu, Bukura, Homabay, Nakuru and Kitale) and are planned in Tanzania and Uganda for the April 2020 cropping maize season. • Discussion with the Ministry of Agriculture, Ethiopia for field testing of entomopathogenic fungi underway.	
6. Habitat management strategies for FAW control optimised and scaled out to smallholder maize growers.	• Habitat management and other cultural practices optimised and scaled out for fall armyworm management in East Africa.	• 25,000 maize growers using fall armyworm control push-pull by 2022.	• Field surveys on diverse maize cropping systems to assess the fall armyworm abundance and natural enemies undertaken in 5 counties of Kenya and 5 districts of Uganda. • Field assessment of push-pull in Central Kenya (Kiambu) and Eastern Kenya (Meru) initiated. • Field surveys in Uganda undertaken to assess the impacts of maize-legume intercropping and push-pull on fall armyworm abundance (Hailu et al. 2018. Agronomy 110, 2513-2522). Fall armyworm and maize stemborer abundance between maize and sorghum assessed. Maize was found to be more susceptible to FAW infestation as compared to Sorghum (Hailu et al. under review). • The climate-smart push-pull technology was widely tested for its effectiveness against fall armyworm in various agro-climatic conditions on 180 field sites in 9 counties in Western Kenya (Bungoma, Busia, Vihiga, Kakamega, Kisumu, Siaya,	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
			Homabay, Migori and Kisii counties) and was found effective in controlling fall armyworm. • A third-generation push-pull, including more drought-resilient companion plants (*Desmodium incanum* and *Brachiaria* cv *Xaraes*) was tested on-station and in five sub-counties in Western Kenya (Suba, Bondo, Siaya, Kisumu and Luanda). The third-generation push-pull was also found to be effective in controlling fall armyworm. • We have researched the mechanisms behind the reduced infestation and have identified several compounds emitted constitutively by *Desmodium* spp. plants such as: (E)-2-hexenal, nonanal, 3-octanone, (E)-β-ocimene, (E)-4,8-Dimethyl-1,3,7-nonatriene (DMNT), methyl salicylate, copaene and (3E,7E)-4,8,12-trimethyltrideca-1,3,7,11-tetraene. The repellent effect of these compounds could explain the reduced infestation of fall armyworm in maize intercropped with *Desmodium*.	
7. Locally adapted fall armyworm-resistant maize cultivars, hybrids and landraces in Africa identified.	• Fall armyworm-resistant maize cultivars available for maize growers.	• At least 1 fall armyworm-resistant cultivar availed and disseminated in partnering countries.	• Laboratory assays revealed higher mortality of fall armyworm in the hybrid WH507, compared with the hybrid Duma and Pioneer and the landraces Nyamula and Rachar. • Hybrids WH507 and Duma and the landrace Rachar were significantly less affected by fall armyworm than the landrace Nyamula.	
8. Implementation of IPM strategy to counter fall armyworm infestation in Eastern Africa jointly with maize crop growers, private sector, NARS, NGOs and growers enhanced.	• Fall armyworm IPM strategy effectively implemented in partnership with maize growers, private sector, NARS, NGOs and growers and widely available for adoption.	• 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 fall armyworm IPM technologies by 2021. • At least 40% of the maize production area affected by fall armyworm (341,262 ha) in the target project areas covered by at least 1 effective IPM option by 2022. • At least 3 technology 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 fall armyworm developed, printed and distributed each year.	• Multiple dissemination pathways, e.g., field days, farmer teachers, farmer field schools, agricultural shows, farmer exchange visits, audio-visual methods, social media and illustrated materials like cartoon books for literacy-challenged farmers, were widely used to scale out push-pull technology reaching 136,691 new farmers (63,314 males and 73,377 females) directly and through partnerships. • A policy brief was developed on push-pull fall armyworm IPM strategy and disseminated. • Control of fall armyworm through push-pull technology was widely disseminated through Kenya Citizen Television series of Shamba Shape-Up, reaching more than 5.5 million people in Eastern Africa. • In Ethiopia, awareness and sensitisation has been conducted in Bako and Ambo Districts. Policy briefs and radio infomercials are underway in the coming seasons. • In Tanzania, the project through TARI Ukiriguru sensitised District Agriculture officers together with extension agents	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
		• At least one fall armyworm microsite developed and maintained.	from all the target Districts of Ilemela, Nyamagana Geita, Bukombe Tarime; Rorya; Bunda, Musoma, Ukerewe, Butiama, Sengerema; Misungwi. A total of 60 ministry officers were reached. • *icipe* Uganda collaborated with NARO, Food for the Hungry, FAO and USAID to implement 3 ToT events and 5 field days involving 671 beneficiaries (405 males and 266 females). • In Kenya, a County Agriculture show was held in Taita Taveta County Kenya between 5-7 December 2019 for 151 participants. • Exhibitions were also done at the Africa-wide Agriculture Extension week organised by AFAAS in Abidjan, Cote d'Ivoire (25-27 November 2019), which registered 383 participants who visited the stand to learn about the fall armyworm management approaches.	
9. Research capacity in Eastern Africa to develop and implement a sustainable IPM strategy for fall armyworm enhanced.	• Enhanced capacity for research among researchers and institutions for development and implementation of fall armyworm IPM strategies.	• 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 one post-doc, 3 PhD and 5 MSc students trained on fall armyworm research by 2022. • At least one open day for policy makers and NARS partners in each year.	• ToT events were organised in partnership with co-applicants RAB in Rwanda and TARI in Tanzania. • 12 ToTs involving 669 participants, of whom 53% were women, were completed. • A farmer field day was conducted at Bukura (Kakamega county) where 100 farmers were trained on the use of biopesticides to control fall armyworm using ICIPE 7 and ICIPE 78 for demonstration. • 3 post-docs and 8 PhD/MSC students are currently trained on various aspects of fall armyworm biology and sustainable management.	
10. Livelihood, environmental and gender impacts of fall armyworm along the maize value chain in Eastern Africa determined and utilised for decision making.	• Socio-economic, environmental and gender impacts of fall armyworm management facilitate promotion of fall armyworm IPM strategies.	• At least 150 high-level stakeholders reached per country with fall armyworm evidence note 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 the sustainable fall armyworm IPM options.	• Farmer's knowledge and management practices of cereal pests, including fall armyworm undertaken in Kenya (Nyangau et al. Under review), Uganda (Nyangau et al. Under review) and Ethiopia (Kassie et al. 2020). • In collaboration with CIMMYT and national partners, detailed economic assessment on the impact of fall armyworm infestation on maize production in Ethiopia (Kassie et al. 2020) and Kenya (De Groot et al. 2020) has been undertaken. • In Ethiopia, the overall average yield loss was estimated to be 11.5%, while in Kenya, the average yield loss was estimated to be 37%.	• More detailed and downscaled economic impact assessment need to be undertaken to guide promotion of IPM strategies.
Objective: Strengthening citrus production systems through the introduction of IPM measures for pests and diseases in Kenya and Tanzania by 2018.				
1. Socio-economic assessment of the importance of the	• Baseline data on farmers' knowledge, attitude and practices of ACP, HLB and	• Baseline data on farmers' knowledge and management practices for ACP, HLB and FCM conducted and information on	• One Msc student graduated with Msc degree in Agricultural Economics, Egerton University (thesis title: Ex-ante economic impact assessment of the integrated citrus pests and	• This study evaluated the potential economic impact of the proposed IPM measures for suppression of ACT and FCM pests and

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
ACP and associated HLB disease, and FCM, and the impact of IPM on target biotic constraints established.	FCM management collected by end of 2015. Economic impact of ACP, HLB and FCM on citrus production established by end of 2016. • Potential impact of IPM interventions evaluated by end of 2016. • Ex-post assessment of implemented IPM management options for target pests and disease conducted by end of 2017.	knowledge, attitude and practices collected in at least one action site by end of 2015. • Economic impact of ACP, HLB and FCM on citrus production assessed in at least one action site by end of 2016. • Potential impact of citrus IPM intervention assessed for at least one action site by end of 2016. • At least one ex-post assessment of implemented IPM management interventions conducted by end of 2017.	diseases management interventions in selected counties, Kenya). • 2 manuscripts published: (1) Gitahi DW, Muriithi B, Owuor G, Diiro G, Mohamed S. 2019. Willingness to pay (WTP) for an integrated pest management strategy for suppression of citrus infesting false codling moth, African citrus *Trioza* and greening disease among citrus producers in Kenya. Journal of Economics and Sustainable Development 10, 443-453; (2) Wangithi CM. 2019. Evaluation of the magnitude of citrus yield losses due to African citrus triozid, false codling moth, the greening disease and other pests of economic importance in Kenya. Journal of Economic and Sustainable Development, 10. • A third paper submitted for peer review (Ex-ante economic impact of integrated citrus pests and diseases management interventions in Kenya).	greening disease in Kenya. Results indicate that IPM investment is economically viable and therefore supports its development and dissemination. • Gitahi et al. (2019) described ex-ante introduction of IPM on farmer's knowledge, perception and practices in regard to ACT, FCN and greening disease, and their WTP for an IPM strategy to address these abiotic challenges. Use of synthetic chemicals was the major control method, however, farmers were willing to switch to IPM as demonstrated by positive WTP. • A significant number of farmers perceived citrus losses due to ACT, FCM and HLB. On average the three abiotic constraints were associated with about 40% of crop loss.
Objective: Promotion of post-harvest disinfestation of key horticultural crops in Kenya and Uganda by 2021.				
1. Infestation of the target crops in the project action site significantly reduced through use of the IPM technologies.	• Preharvest disinfestation treatment of the key target pests on the target crops applied on large scale; preharvest pest infestation reduced by 10-15%.	• Preharvest infestation level by the key pest on the target crops reduced by at least 10-15% by end of 2018.	• 4 ToTs were conducted in Kenya and Uganda, with 75 male and 33 female farmers trained. • 2 field days were conducted in Kenya with 321 male and 274 female farmers trained. • During trainings, traps and lures were distributed to the farmers.	• The male annihilation technique is the most popular fruit fly management measure, due to the fact that farmers can physically see the killed fruit flies. More effort is required in promoting the whole IPM package.
2. Postharvest disinfestation treatment of thrips on French bean and false codling moth on bell pepper established.	• Quality of vegetables improved through implementation of postharvest disinfestation treatment.	• Developmental duration for immature stages and the most heat-tolerant stage of false codling moth on bell pepper established by mid 2019. • Heat treatment parameters required to achieve Probit 99.9968% for false codling moth on bell pepper established by mid 2019. • Impact of treatment on vegetable nutritional quality established by end of 2019. • Medium scale postharvest disinfestation trials against thrips on French beans validated by end of 2019.	• Experiments at *icipe* have shown that bell pepper requires a temperature of 50°C to effectively disinfest false codling moth. • More work is currently in progress to determine the effective time required to subject infested bell pepper to achieve export requirements. • Similar work is also in progress at NARL in Uganda. The FCM colony was initiated from insects collected from farms in Wakiso district as well as from packhouses	• Bell pepper and French beans require less treatment duration than mangoes due to the nature of their skin. This has been factored in the treatment protocol.
3. Proven postharvest disinfestation treatment of mango	• Quality of fruits improved through implementation of	• Large-scale trials on avocado (cold treatment) validated by end of 2018.	• Validation was done on the mango variety Tommy Atkins in Uganda. The effective regime was 86.71 minutes at 46.1°C,	• Recent requirements by the EU point to postharvest treatment being the most viable option at the moment. The protocols for

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
and avocado against fruit flies validated.	postharvest disinfestation treatment.	• Large-scale trials on mango (heat treatment) validated by end of 2018.	compared to 81.47 minutes at the same temperature obtained in Kenya on the Apple mango variety.	disinfesting Tommy Atkins and Apple mango varieties will go a long way in accessing the EU market if implemented by exporters of mango.
4. Awareness and capacity on the postharvest treatment of the target crop pests among various stakeholders, including policy makers, enhanced.	• Knowledge of the use of hot water disinfestation treatment among the partner entrepreneurs enhanced.	• At least two private entrepreneurs trained on postharvest treatment technologies by end of 2018. • At least 1,000 growers trained on preharvest IPM measures of fruits and vegetables as a prerequisite for successful implementation of postharvest disinfestation treatment as a prerequisite for successful implementation of post-harvest disinfestation treatment by end of 2018. • At least two policy briefs on the use of postharvest disinfestation treatments developed and circulated to policy makers and other stakeholders by end of 2019. • Policy makers and other stakeholders are aware of the availability of postharvest disinfestation treatments by end of 2019. • At least one PhD and one MSc student trained on various aspects of postharvest disinfestation treatments by end of 2020.	• Three private sector partners namely Kibwezi Agro, Afri Foods (Kenya) and Sulma foods Ltd (Uganda) have been trained on postharvest treatment technologies. • A total of 703 mango farmers were trained. • *icipe* made a presentation to the Horticulture Competent Authority Structure (HCAS) on the way forward regarding the establishment and commissioning in Kenya, of the first hot water treatment facility to treat mango destined for the EU. • One MSc student from Uganda has completed studies and will be graduating after the COVID-19 situation is over. The PhD student in Kenya is still collecting data.	
5. Pilot postharvest disinfestation treatment plant for fruits and vegetables established and operationalised.	• Postharvest disinfestation treatment implemented by the partner entrepreneurs.	• At least one postharvest disinfestation plant established in the project countries by mid of 2019. • At least one postharvest disinfestation plant becomes operational by end 2019.	• Plans to jointly visit Pakistan with Afrifoods to identify suitable equipment were shelved owing to the COVID-19 pandemic. • Plans were to acquire the equipment and establish a hot water treatment facility for mangoes in Athi River, managed by Afrifoods.	
6. Certification, standards of fruit and vegetable post-harvest treatment established.	• Rule and regulation governing the use of the postharvest hot water disinfestation treatment shared and harmonised among the partner entrepreneurs.	• At least one harmonised protocol developed by end of 2019.	• Once the treatment facility is established, the harmonised protocol will be developed. Currently we have procedures for fruit fly management.	
7. Access to lucrative export markets regionally and international for the	• Zero infestation of the target crop by the target pest at points of export. • Access to lucrative export market regionally and	• At least two awareness campaigns among policy makers on the efficiency of the postharvest disinfestation treatments conducted by end of 2019.	• A stakeholder's workshop was conducted at NARL Kawanda to create awareness on hot water treatment of mangoes. It was attended by a total of 67 participants drawn from exporters, farmers and government departments. The workshop generated lots of interest and the project team has	• Exporters are reluctant to invest in establishing hot water treatment facility most likely because they are currently exporting to the Middle East which is less stringent. The project team may need to conduct

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
target commodities facilitated.	international for the target commodities regained.	• The entrepreneurs are able to access at least one regional/ international export markets by 2020.	received a number of enquiries, but none have been backed up with commitment.	awareness campaigns backed by financial and economic data e.g. payback periods, break even points and net present value.
Objective: To enhance productivity of avocado and cucurbits among smallholder growers in East Africa through integrated pest and pollinators management (IPPM).				
1. Avocado-cucurbit-production systems in diverse agro-ecologies characterised for the role of pollinators and insect pests, and associated extrinsic and intrinsic factors.	• Avocado-cucurbit- production systems in diverse agro-ecologies assessed.	• Landscape dynamic for cucurbit-avocado production systems in 3 diverse agroecology characterised by 2019. • Species composition and genetic diversity of insect pests and pollinators and their abundance on target crops in 3 production systems assessed by 2018. • Pollination deficit in the target crops assessed in at least 3 landscapes by 2019. • Symbionts in key pests and pollinators of cucurbits and avocado characterised by 2019.	• Two avocado production systems (Kilimanjaro, Tanzania and Muranga, Kenya) have been characterised according to cropping systems, land use/land cover and agroforestry. Characterisation of one cucurbit system (Machakos, Kenya) is ongoing. Pest densities (fruit flies and false codling moth) have been linked to avocado systems. Best agricultural practices have been documented during the baseline and knowledge, attitude and practices (KAP) surveys. • The genetic diversity of honeybees and their abundance has been established on avocado and is ongoing for cucurbits. This has resulted in 2 publication (Bonilla-Rosso G, Paredes JC, Das S, Ellegaard KM, Emery O, Garcia-Garcera M, Glover N, Hadadi N, Van Der Meer JR, Tagini F, Engel P. 2019. Acetobacteraceae in the honey bee gut comprise two distant clades with diverging metabolism and ecological niches. BioRxiv, 861260; Siozios S, Moran J, Chege M, Hurst GDD, Paredes JC. 2019. Complete reference genome assembly for *Commensalibacter* sp. Strain AMU001, an acetic acid bacterium isolated from the gut of honey bees. Microbiology Resource Announcements 8, 1-2). • Pollination deficit has been assessed for avocado in Muranga, Kenya. • Key symbionts of honeybees have been characterised on avocado.	• This project made great strides in mapping of land use/ land cover, and farming and cropping systems in heterogeneous African landscapes, including production of the first maps for Kenya and Tanzania that considers agro-forestry systems. Coupled with climatic data, we modelled the distribution and abundance of avocado pests and pollinators for the first time in Africa, and ultimately now know what drives the performance of IPM, pollination services and IPPM. The maps are important advisory tools for identifying pest and pollinator risk zones for intervention and habitat protection, and therefore have major policy implications. • In the project, pollination deficit was, for the first time, established for avocado in Kenya at 27% as fruits set. We showed that pollination services closes this gap, increasing avocado income by ~168 USD/farmer/season or ~158,088 USD for the direct beneficiaries.
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 characterised 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 by 2019. • The nature and magnitude of interactions between the pollinators and IPM practices documented by 2020.	• Pest management practices have been assessed for avocado and cucurbits, while floral cycles are being innovatively assessed using pollen traps at the entrance of beehives. • In the laboratory, novel fungal strains have been identified against fruit flies. This has resulted in a publication (Onsongo SK, Gichimu BM, Akutse KS, Dubois T, Mohamed SA. 2019. Performance of three isolates of *Metarhizium anisopliae* and their virulence against *Zeugodacus cucurbitae* under different temperature regimes, with global extrapolation of their efficiency. Insects 10, 270). • The effect of commercial biopesticides has been assessed on honeybees in the laboratory.	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
		• Impact of integrating pollination and IPM on key cucurbit and avocado pests and pollinators' health established by 2019.	• On-farm validation of existing and new IPM options that enhance pollinator diversity is ongoing. 4 existing (biopesticide, protein food bait, male attractants, sanitation) IPM options are implemented, while new IPM options (biopesticide autodissemination, new fungal strains) are being tested.	
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) by 2020. • Sustainable pollination and best-bet IPM options for cucurbits and avocado promoted by 2020. • Impact of enhanced pollination services and IPM on avocado-cucurbit system productivity established by 2020.	• Through 92 large on-farm trials, IPM, pollination services and IPPM are being tested in Tanzania (avocado) and Kenya (avocado and cucurbits). • IPM, pollination supplementation and IPPM are being demonstrated and promoted through farmer-of-farmer trainings and demonstration gardens at some of the 92 farms. • One PhD student is conducting research on interactions between integrated pest and pollinator management. • One MSc student has finished her study on biopesticide development for cucurbit pests.	• IPPM is knowledge-intensive and several drivers emerged that may speed up IPPM adoption and dissemination. Beekeeping has emerged as a key driver for IPPM adoption. This is especially the case for stingless bees, as stingless beekeeping may be more suitable for smallholder farmers. In addition, sharing or renting of honey beehives needs to be explored through linking farmer groups with professional beekeepers.
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 by 2020. • Impacts of IPPM interventions on livelihoods of cucurbits and avocado producers documented by 2020. • Ex-ante adoption of IPM pollination services documented by 2020.	• Baseline survey data was collected in January-February 2019 among 410 avocado farmers in Kenya. • Data have been synthesised in one Msc thesis and one draft manuscript (Farmers knowledge and perception, and willingness to pay for an integrated pest and pollinator management (IPPM) innovation in Murang'a County, Kenya). • One MSc student graduated on 20 December 2019 at the University of Nairobi. • A baseline survey consisting on 420 avocado growers was conducted in April-May 2019 in Tanzania. • A baseline survey involving 90 cucurbit growers was conducted in July 2019 in Kenya.	• Although a knowledge gap was observed, farmers depicted positive WTP for the innovation of IPPM in Muranga, Kenya. • Our studies revealed a positive return to IPPM investment.
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 training-of-trainer (ToT) and 4 farmer field days on integration of IPM and pollination services, targeting 6,100 beneficiaries, held by 2020. • At least 2 PPP agreements formed to enhance availability of IPPM products for end users. • At least 3 awareness events targeting growers and policy makers held by 2020. • At least 3 PhD and 2 MSc students trained on bee symbionts, integration of IPM with pollination services and	• 941 farmers (766 M/175 F), 25 extensionists (12 M/13 F) and 28 NARS staff (17 M/11 F) were trained as experts in Kenya and Tanzania. • Training materials were produced and used in training-of-trainers for farmers and extensionists. • A total of 14 students (11 MSc, 3 PhD; 4 M, 9 F) are conducting research in the project. • Four public-private partnerships were formed with Africado, Kakuzi, RealIPM and Kenya Biologics. A workshop with all stakeholders was conducted during 19-20 August 2019.	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
		GIS/earth observation tools by end of 2020.		
Objective: To implement, disseminate and promote, a sustainable and eco-friendly integrated pest management (IPM) approach for reduction of tomato losses due to *T. absoluta* infestation leading to increased yield and quality of tomatoes in east Africa.				
1. Baseline socio-economic assessment prior to the *T. absoluta* IPM intervention undertaken.	• Baseline socio-economic assessment prior to the *T. absoluta* IPM intervention evaluated by 2021.	• Reference point data and information on *T. absoluta* socio-economic impact on tomato growers' livelihood prior to the intervention collated and documented by 2019. • Logistic forecast models and forecast data generated by 2019.	• One Msc student has been hired to address this objective of the project. • A baseline (household) level survey involving 141 and 179 tomato growing households in Kenya and Uganda, respectively, was conducted.	• Preliminary findings indicate that *T. absoluta* is a major tomato-infesting pest, reported by 99% of the respondents, and mainly controlled using synthetic pesticides. • 99% of the respondents cited *T. absoluta* as the most damaging pest of tomatoes and reported widespread and intensive application of synthetic pesticides to control the pest. Therefore, there is an urgent need to implement IPM to significantly reduce synthetic pesticide usage.
2. Performance of introduced parasitoid *D. gelechiidivoris against T. absoluta* assessed and the use of the identified potent *M. anisopliae* fungal isolates under field conditions validated.	• Performance of introduced parasitoid *D. gelechiidivoris against T. absoluta* established. • Efficacy of identified potent fungal isolates validated under field conditions.	• Level of percent parasitism of *T. absoluta* by *D. gelechiidivoris* documented by 2019. • Reduction of *T. absoluta* population as a result of *M. anisopliae* application documented by 2021.	• Laboratory findings on host specificity and acceptability have been published: Aigbedion-Atalor et al. (2020) Biological Control, 144, 104215. The parasitoid prefers only *T. absoluta* and percent parasitism was 73%.	• Mass production of the parasitoid on tomato plants in the greenhouse or laboratory has challenges as it is difficult to obtain adequate numbers. There is urgent need to fast-track the formulation of artificial diet.
3. Awareness on management of *T. absoluta* using IPM approach among various tomato value chain stakeholders created and capacity of various stakeholder on the intervention enhanced.	• Knowledge and skill of the tomato growers, extension officers and other stakeholder on *T. absoluta* using IPM enhanced. • Cohort of trained young scientist on various aspect of *T. absoluta* created.	• At least 3 ToT workshops for NARS conducted in the project action sites by 2021. • At least 90 agricultural personnel and extension/ quarantine officers identified and recruited for project implementation by 2021. • At least 1 model farmer identified in each project action site by 2021. • At least 1 IPM learning site identified and used for dissemination of a *T. absoluta* IPM package in each project action site by 2021. • At least 6 farmer field days conducted in the project action sites by 2021.	• 3 ToTs were conducted in Kenya (Kitui, Kirinyaga and Taita Taveta). • In these ToTs, 39 agricultural extension officers were trained (26 male and 13 female). In addition, 3 schoolteachers, and 1 tomato trader were also trained on *T. absoluta* management. • 24 farmers have been trained in 3 ToTs in Kitui, Kirinyaga and Taita Taveta (20 male and 4 female). Signage has been erected on demonstration farms in Kitui. • A total of 8 farmer field days were conducted in Taita Taveta, Kirinyaga and Kitui. • Branded polo T-shirts (100), brochures (1,000), were produced during the reporting period. • 2 MSc students and 2 PhD students are currently enrolled in the project and working on various aspects of *T. absoluta* and its parasitoid.	• There is a big knowledge gap in terms of pests and diseases control. Though *T. absoluta* is being managed successfully using the *icipe* developed IPM package, farmers are still applying huge amounts of synthetic pesticides to control other pests and disease. There is need to introduce a holistic approach to pests and disease management, if farmers are to produce clean residue-free tomatoes.

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
		• At least 1 awareness campaign conducted through different media (e.g. on local radio stations, TV, farmer magazines, etc.) by 2021. • At least two PhD students trained in the project lifespan on fruit fly management 2021.	• 7 ToTs workshops were conducted in Kenya, with 58 farmers trained. In Tanzania, 1 workshop was held at TARI with 21 farmers trained. In Uganda 2 workshops were conducted: 1 in Mbale with 21 farmers trained and 1 in Kapchorwa with 20 farmers trained. • 114 extension officers and 38 model farmers were trained. • 7 farmer field days were conducted in Kenya, Tanzania and Uganda. We trained a total of 1,034 farmers (655 male and 379 female). • Two brochures were developed on biology and IPM of *T. absoluta*, and 2,000 were distributed in the 3 countries. • 2 banners were made as well as branded polo T-shirts (486 pieces). • 4 MSc students and one PhD students are currently enrolled in the project and working on various aspects of *T. absoluta* biology and management.	
4. Implementation of a proven integrated pest management (IPM) strategy against *T. absoluta* upscaled in East Africa.	• Increased production of quality tomato and grower's income.	• At least 60% reduction in *T. absoluta* population in tomato greenhouses and open fields by 2021. • At least 50% reduction in infestation of tomatoes by *T. absoluta* by 2021. • At least 70% reduction in expenditure on broad spectrum synthetic pesticides targeting *T. absoluta* by 2021. • At least 50% increase in yield quantity and quality by 2021.	• Trainings and awareness campaigns have been conducted, IPM starter packs have been distributed to tomato growers.	• Tomato growers encounter huge challenges in accessing components of the *T. absoluta* IPM package in their areas of residence. The project must ensure that partnerships with companies such as RealIPM, Kenya Biologics, and Farm Track result in the availability and accessibility of traps, lures and biopesticides to the farmers.
Objective: Promoting smallholder access to fungal biopesticides through Public and Private Partnerships in east Africa by 2021.				
1. Strengthen public-private partnerships (PPPs) for development, production and promotion of biopesticides in East Africa.	• PPPs for commercialisation of biopesticide expanded between partners, strengthened through mutual and better understanding of strengths, weakness, opportunities and threats.	• At least 3 PPP agreements signed by second quarter of 2018. • Business opportunities workshop organised by first quarter of 2018. • At least one market survey and SWOT reports accomplished by end of 2018.	• Steering Committee meeting organised. • Market surveys conducted and SWOT analysis completed. • MTAs for ICIPE 7 and ICIPE 78 revised for label extension. • MTA for ICIPE 41 under revision for approval. • One socio-economic scientific paper on willingness to pay for biopesticides submitted for publication. • One regional sensitisation workshop on biopesticides against fall armyworm organised.	
2. Develop improved biopesticide formulation and application strategies for enhanced efficacy of potent	• Innovative biopesticide products, their formulation and application strategies adopted by private sector for commercialisation.	• At least 2 innovative formulation and application strategies of biopesticide developed and communicated by mid-2019.	• One potent isolate identified for biopesticide development against whiteflies. • 4 MSc student recruited (topics: endophyte-stimulated metabolites characterisation, field efficacy on *T. absoluta* and fall armyworm, new biopesticide formulations, bioprospecting).	• The identification of fungal-based new biopesticides against fall armyworm as well as fast-tracking their registration in Kenya, Uganda and Tanzania could really influence the outcome of *icipe*'s Biopesticide

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
biopesticides products.		• Potent biopesticides for at least 2 new and emerging pest identified by end of 2019.	• Potent biopesticide with ovicidal activity against fall armyworm identified and a scientific paper published. • Potent biopesticides against adult fall armyworm identified and scientific paper drafted for submission. • Compatibility of fall armyworm pheromone and potent fungal-based biopesticides established. • 3 field efficacy trials for biopesticide efficacy against fall armyworm conducted in Kenya. • 2 farmer field demonstration trials for biopesticide against fall armyworm established. • Label extension for ICIPE 78 initiated. • Fast-track registration of ICIPE 7 against FAW initiated. • One potent fungal-based biopesticide identified against whiteflies. • Endophytic-based biopesticide developed against cryptic stage of *T. absoluta* and one scientific paper drafted and revised for submission. • One abstract submitted and accepted for PHAB 2020.	Consortium agenda with significant impact on small-scale farmers in the region.
3. Optimise biopesticide mass production and quality control methods at for various scales	• Enhanced production of biopesticide products by private sector partners, women and youth groups engaged in the project for various pest targets.	• At least one validation and training facility on small-scale biopesticide production established at *icipe* to train youth and women on biopesticides by end of 2018. • At least two small-scale production facility involving women and youth groups established and operationalised by end of 2020. • At least one industry scale pilot mass production facility for biopesticides established by mid 2020 with private sector partners.	• Eight potential entrepreneurs belonging to farmer groups trained on small scale biopesticide production. Further follow-up trainings are planned in 2020. • Several ToT trainings conducted in project target countries. • Purchase of equipment and instrumentation on-going, for the training facility to be fully established in 2020. • Pilot production unit site identified and prepared for the production unit establishment. • Purchase of equipment and instrumentation on-going, for the pilot production unit to be established in 2020.	
4. Register and commercialise new biopesticide products in East Africa.	• New biopesticide product registered for use in integrated pest management of pests in the target countries.	• At least two PPP agreements signed for product commercialisation by mid of 2019. • Eco- and mammalian toxicity of at least two biopesticide products/formulation accomplished by first quarter of 2020. • At least 2 dossiers for product registration submitted to regulatory authorities by mid of 2020.	• Registration dossiers were submitted to PCPB, Kenya for commercial registration through label extension of ICIPE 78 (Achieve®) as biopesticide against the fall armyworm. • Field efficacy trial permit was obtained from PCPB for ICIPE 78 label extension. • Label extension registration dossier for ICIPE 7 has been submitted to PCPB to fast-tracking the product as Detain® for fall armyworm control in Kenya. • Registration dossiers for ICIPE 7 and ICIPE 78 have been submitted to NBCC, Tanzania to fast-tract registration as Detain® & Achieve® for fall armyworm control.	

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
			• Field efficacy trial permits were granted for ICIPE 7 and ICIPE 78 by MAAIF through Crop Inspection and Certification Board. • One registration field efficacy trial has been undertaken in Kenya for ICIPE 78 label extension. • Eco- and mammalian studies initiated for ICIPE 78, F3ST1 and G1LU3.	
5. Transfer technology and build capacity on biopesticide research and use to multi-stakeholders.	• Enhanced awareness and capacity among various stakeholders on biopesticides, their efficacy, production technology and enabling policy leading to increased adoption of biopesticides.	• At least 10,000 smallholders made aware of the use of new biopesticides for management of target pests by end of 2019. • Small-scale biopesticide production established, optimised and operationalised by at least two women/youth groups by end of 2019. • At least one sensitisation and awareness campaign for policy makers and other stakeholders with 25 participants on biopesticides in East Africa undertaken by end of 2020. • At least 2 MSc and 1 PhD student trained on biopesticide research by end of 2020.	• Partnership between HottiServe, RealIPM and UoN strengthened for demonstration of biopesticide products use. • Several ToT trainings conducted in project target countries. • 6,384 households were reached on the use of biopesticides. • Participatory field demonstration of efficacy of fall armyworm biopesticides undertaken and multilocation trials ongoing. • One farmers field day conducted. • One regional sensitisation workshop for policy and regulatory authorities on biopesticides organised. • Training on small-scale production conducted. • Meetings with PCPB to facilitate biopesticide registration undertaken. • 4 MSc students recruited. • 1 PhD recruitment initiated for endophyte studies against fall armyworm.	• Key stakeholders in biopesticides registration sector, including Secretary of East Africa Community for harmonised guidelines, National Biological Control Program from Tanzania, Kenyan Ministry of Agriculture, Ethiopia Plant Protection Directorate, Ministry of Agriculture, Pest Control Products Board (PCPB) of Kenya, Kenyan Plant Health Inspectorate Service (KEPHIS), Department of Crop Inspection and Certification, Ministry of Agriculture Animal Industry and Fisheries from Uganda, were well represented during the regional sensitisation workshop. This really facilitates the fast-tack registration process of the key potent biopesticides.
Objective: To improve food and nutrition security, conserve environment, and to increase income and improve health of resource-poor farmers (including women farmers), by reducing crop losses and pesticide use through development and dissemination of effective pest management practices, especially IPM, in East Africa, along maize, rice and chickpea value chains by 2019.				
1. Production and productivity along maize, rice and chickpea value chains, by reducing crop losses through dissemination of effective IPM options increased.	• At least 30% reduction in crop losses (from the baseline) in target communities by 2019. • At least 30% increase in yield (from the baseline) in target communities by 2019. • At least 30% reduction in frequency pesticide applications by 2019. • At least 20% increase in household incomes from adoption of IPM practices by 2019. • At least 50% farmers apply IPM practices. • At least 70% farmers beneficiaries understand pest	• Number of beneficiaries engaged in IPM technology evaluation and adoption. • Percentage reduction in pesticide use in beneficiary communities. • Number of extension agents, farmers and graduate students trained. • Percent yield loss abated in beneficiary communities.	• Socioeconomic data on reduction in crop losses, increase in yield and reduction in frequency pesticide applications are being collected in target countries. • Data on an increase in household incomes from adoption of IPM practices was collected for Ethiopia. • About 40% target or beneficiary farmers apply IPM practices. • About 70% farmers beneficiaries understand pest damage and losses. • 8 PhD/MSc students graduated. • Over 500 farmers and extension agents trained.	• Changing behavior farmers from pesticide application to adoption of IPM practices takes time. • With an outbreak of new invasive pests such as fall armyworm, farmers would rush to pesticides application. • Implementation of IPM practices take concerted effort from all partners (farmers, extension, research, policy and market). • Training extension agents is crucial in convincing farmers about IPM technologies.

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
	damage and behavior. • At least 25% reduction in the frequency of pesticide application. • 6 PhD/MSc students trained. • Over 800 farmers and extension agents trained by 2019 (200 a year for 2016, 2017, 2018 and 2019).			
2. Key partners identified, IPM technologies developed and implementation strategies defined for sound sustainable intensification along the maize, rice and chickpea value chains.	• Identify key stakeholders and develop implementation strategy by mid 2016. • Problem identification and prioritisation by mid 2016. • Design and conduct on-farm and on-station IPM participatory trials for rice, maize and chickpea pests, diseases and weeds by early 2017. • Evaluation and assessment of IPM packages and implementation strategies by mid 2017. • Scaling up proven IPM technologies under sustainable intensification systems by end of 2019.	• Number of stakeholders participated. • Number of pest problems identified and prioritised per crop per country. • Number of respondents interviewed (baseline survey). • Number of on-farm trials conducted. • Number of farmers participated. • Number of demo trials. • Number of IPM packages evaluated. • Percent crop loss abated.	• Ethiopia: Ethiopia Institute of Agricultural Research (EIAR). Bako Agricultural Research Centre (National Maize Program); Debrezeit Agricultural Research Centre (National Chickpea Program); Ministry of Agriculture and Natural Resources (MANR) of Hawassa Regional State; Bureau of Agriculture and Natural Resources; Ambo University; Haramaya University; Addis Ababa University; and Jimma University. • Kenya: Kenya Agricultural and Livestock Research Organisation (KALRO): National Agricultural Research Laboratories (NARL- Nairobi); Nakuru and Naivasha counties Department of Agriculture; Kipkelion East Sub-County; AUSAID/Kenya Agricultural Value Chain Enterprises (KAVES) office; and Kipkelion East Sub-County Agriculture office (Londiani). • Tanzania: Agricultural Research Institute (ARI Dakawa); National Biological Control Programme (Kibaha); Sokoine University of Agriculture; RealIPM (private sector). • Implementation strategies developed. • Key pest problems identified and prioritised. • Several on-farm and on-station IPM participatory trials for rice, maize and chickpea pests, IPM conducted. • Proven IPM technologies were scaled in rice, maize and chickpea	• Identification key partners in collaboration with the ministry of agriculture is important in creating ownership of the project. • Participatory problem identification and priority setting avoids conflict of interest during project implementation. • Sensitisation of famers is important before establishing on-farm trials. • Scaling up proven IPM technologies requires active participation of private sectors (supplies), government authorities and development agents.
3. Pragmatic pest diagnostic capacity developed.	• Identifying local diagnostics and national pest, diseases and weeds priority by mid 2016. • Developing and testing diagnostic kits by end of 2016. • Capacity building and in-depth training on high impact pest and disease diagnosis by end of 2018.	• Number of scientists/institutions engaged. • Number of pests, diseases and weeds identified and prioritised. • Types of diagnostics identified. • Number of kits developed and tested. • Number of institutions tested the kits. • Number of people trained (short-term and long- term trainings).	• Capacity of national partners built through in-depth training on high impact pest and disease diagnosis. • Identified local diagnostics challenges and national pest priority. • WhatsApp and telegram communication network systems with partners established.	• Target countries don't have the same level of pest diagnostic practices; hence, should be treated differently. • Plant health clinics are active in Ethiopia compared to Kenya and Tanzania. • The national plant health laboratories are not able to deal with new pests.

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
	• Communication and data-network systems with partners by end of 2019.	• Number of pests, diseases and weds diagnosed. • Number of people accessing data.		
4. Integrated pest management (IPM) communication and education improved.	• Develop tailor made communication strategy for IPM to address different stakeholders by mid 2016. • Create awareness and disseminate information on IPM to enhance responsiveness of the stakeholders from 2016-2019. • Develop promotional materials targeted to different stakeholders to enhance up-take of the IPM technologies in 2016 and in 2018. • Establish network of key stakeholders in IPM through a web-based interface that allows stakeholders to continually access emerging policy messages from the project by mid 2017. • Conduct training need assessments and educate farmers and extensions agents by end of 2018.	• Communication strategy developed. • Number of audiences addressed. • Number of people aware of IPM practices. • Number of people applying IPM practices. • Number of targeted stakeholders reached through these awareness campaigns. • Number of promotional materials developed. • Number of promotional materials disseminated. • Number of people accessing the web-interface. • Number of documents downloaded. • Types of training needs assessed. • Number of farmers and extension workers trained.	• Awareness created among stakeholders and IPM information disseminated. • Several promotional materials developed and disseminated to stakeholders to enhance uptake of the IPM technologies. • Several extension agents and farmers trained.	• Farmers are hesitant to practice IPM technologies when first introduced. • Farmer to farmer communication of IPM technologies are effective. • Recognizing lead farmers with certificate awards during field days are motivating other fellow farmers.
5. Information and capacity building to reform and strengthen policies that influence integrated pest management provided.	• Identification of incentives and disincentives, policy gaps and institutional arrangements for adoption of IPM by early 2017. • Conduct a cost-benefit analysis for IPM options for maize, rice and chickpea by early 2017. • Conduct evidence-based policy dialogue to improve adoption of IPM from mid 2017-2019.	• Number of institutions participated. • Policy gaps identified. • Internal rate of return. • Net present value. • Number of policy briefs. • Number of policy workshops.	• Incentives and disincentives, policy gaps and institutional arrangements for adoption of IPM was studied and working documents produced. • Cost-benefit analysis for IPM options for maize was conducted in Ethiopia and Kenya. • Annual workshop was conducted with key national partners to improve adoption of IPM.	• IPM is not properly recognised by policy makers. • There is knowledge gap on IPM from the government policy advisors. • Most government production policies are dominated by supplies of pesticides, fertilisers and improved seed.
Objective: MUSA - Microbial Uptakes for Sustainable management of major banana pests and diseases evaluated by 2020				

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
1. Microbial collections (fungi) and other beneficial EBCAs (endophytes and biological control agents) for IPM in banana.	• At least 8 EBCAs discovered and identified. • Collected EBCAs cultured and deposited in *icipe* collection.	• Number of EBCAs discovered and identified. • Number EBCAs successfully in culture.	• 19 fungal isolates selected for screening (15 *icipe* isolates and 4 from RealIPM) against banana weevil and banana nematodes. • 4 bacterial isolates (IITA) selected for screening against banana nematodes.	• *icipe* (EBCAs) fungal and bacterial collections have much potential for screening against plant parasitic nematodes, more screening recommended.
2. EBCAs host range assessment.	• A number of selected EBCAs active against at least 2 pests in banana (plant parasitic nematodes (PPN) and banana weevil (BW)).	• Number of EBCAs successful in control of at least 2 pests in banana.	• 3 *icipe* fungal isolates selected for further testing against banana weevil. • 4 *icipe* isolates (endophytes) selected for further testing against banana nematodes; on-going experiments to compare efficacy of endophyte concentrations against banana nematodes in TC (tissue culture) banana. • Exposure of banana nematodes to the bacterial filtrates resulted in 78% mortality for one of the isolates.	
3. EBCAs biology in plants, pests and pathogen interactions.	• Data on biology and effectiveness of selected EBCAs obtained.	• Knowledge on biology and effectiveness of selected EBCAs.	• The 3 successful fungal isolates selected for banana weevil control gave over 50% weevil mortality. In addition, the isolates produced high spore concentrations on the weevil cadavers, a potential for autodissemination. • Dose response experiments conducted. • Efficacy of *Fusarium oxysporum* and *Beauveria bassiana* against banana weevil damage in TC banana plants ongoing. • Efficacy of *Trichoderma asperellum* (RealIPM) tested against banana nematodes in banana TC plants in forest soil and coco peat media. • Efficacy of *Beauveria bassiana* and *Fusarium oxysporum* tested against mixed banana nematodes in TC banana plantlets. Isolates were inoculated into plantlets singly and in combination.	
4. Procedure for EBCAs mass production, storage and application.	• Methods for large scale cultivation of microbial EBCAs bio formulation and storage.	• Identification of the most appropriate EBCAs culturing methods. • Protocol drafts available for partners.	• Ongoing.	
5. Field integration of EBCA-based IPM.	• Field data for integration of EBCA (fungi) based IPM against PPN and BW.	• Field trial data.	• Assessing field performance of TC banana plants following single and dual inoculation of the fungal endophytes *Beauveria bassiana* and *Fusarium oxysporum*. • Plant flowering and yield data were collected on a weekly basis, in addition to collecting data on nematode and weevil infestation levels for every toppled, snapped, flowered and harvested plant.	
Overall Objective: Minimise the vulnerabilities of horticulture and staple crops to climate change-induced pest problems by at least 10% by 2020.				

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
Objective: Predicting climate change that induced vulnerability of African agricultural systems to major insect pests through advanced insect phenology modelling, and decision aid development for adaptation planning by 2016.				
1. Baseline information on pests' life table according to the temperatures along altitudinal gradients, soil and plant biophysical characters, farmer practices and their impacts on agro-ecosystem influencing the pest density and communities, competitions assessed.	• Climate change-induced vulnerability of African agricultural systems to major insect pests predicted through advanced insect phenology modelling, and decision aid developed for adaptation planning by 2015.	• Development of predicting models combining different parameters evaluated at least for three major insect pests by the group by 2015.	• An algorithm for data reconstruction from published articles to derive insect life tables published (Kareithi et al. 2019. Cogent Mathematics & Statistics).	
Objective: Implement innovative pest biocontrol technologies for sustainable intensification of fruit production systems in Kenya and Senegal by 2021.				
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.	• One baseline survey in at least two sites in Kenya and Senegal by end of 2019. • At least one working paper by mid-2020.	• Draft manuscript produced (Barriers and opportunities for scaling up sustainable agricultural innovations: A case of fruit fly IPM technologies in the Kenyan mango farming systems).	• The study seeks to track farmer's innovations in management of invasive fruit flies and access their adoption of an IPM approach developed and promoted by *icipe*. The findings reveal that, although farmers are aware and some use the IPM technologies, they still heavily depend on synthetic pesticides (90%), as well as indigenous methods (35%) to manage the pest
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 in at least two sites in Kenya and Senegal by end of 2021 • At least one peer review manuscript by end of 2021.	• Baseline data that will provide the benchmark for impact assessment was conducted as above.	• Although farmers' knowledge regarding fruit fly IPM have significantly improved and impact evident, dis-adoption of the innovations is evident, primarily attributed to limited accessibility of the IPM products in the market and poor crop production.
Objective : To generate sustainable wealth creation for improved livelihood and poverty alleviation in rural areas, through green economy and sustainable consumption and production (SCP) promotion in Africa.				
Specific Objective. Implementing and achieving the triple certification scheme.				
1. A trained operational structure (staff, organisation,	• Mt Rwenzori coffee production chain is capacitated and empowered.	• Training publication (factsheets, guidebooks) by September 2019.	• Farmer organisation network created and developing: 21 cooperatives now participate, representing 11,200 producers.	• Local and national authorities have fully endorsed the GI concept and fully support it.

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
equipment) in charge of the project implementation; project database created; 21,000 contracts with farmers for certification.	• An organised structure is created, which is suitably trained and equipped, and meant to remain operational after the termination of the project.	• A practical handbook on triple certification scheme. • GI book of requirements.	• In collaboration with NUCAFE coffee farmer union, implementation of a permanent training program about coffee BAP and certification. • Workshops (2), seminar (3) and training program about GI organised in Rwenzori. • A national task force on GI is created (participation of URSB, UCDA, and various Ministries).	• Farmers' needs are important for information, technical transfer and management skills.
Specific Objective. Creating and implementing a dynamic, interactive knowledge platform, supporting the project development.				
1. The basic structure of the information system is created; WIFI, mobile phone, Interfaces development; a GIS system-based, descriptive and dynamic presentation of Mt Rwenzori certified coffee production; a production traceability platform interface.	• It provides a powerful organisation 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 project management and commercial interface (relation with buyers).	• A mobile application developed for P&D monitoring in Rwenzori area. • A detailed IT procedure has been designed and made operational for full coffee production traceability, from field to export. • The platform structure is designed and operational. • Detailed maps of the region generated (topography, administration, production site). • Farmers' database created.	• Although internet connectivity is not optimal in the area, it is good enough to permit direct access from the field to the platform. • An important effort is to be developed to ensure data collection and data reliability.
Specific Objective. Generating conditions for sustainability; SCP promotion.				
1. Expertise transferred to and acquired by NUCAFE in the domains of IT, quality management, certification programs implementation.	• Farmers' coffee income is improved by a minimum of 35% from certification premium obtained through the general improvement of Mt Rwenzori CVC performance.	• Quality management procedure. • Recruited staff position. • Social and legal prospective study developed.	• Participation of NUCAFE staff (2) to the international training course about GI (November 2018, Setes, France) • Support to NUCAFE quality lab to develop quality management procedure: sample collection, quality characterisation, analysis, reporting, mapping • A project Internal Control procedure is designed (with IT support) to implement the certification program (registration and verification for FT, Org, GI). • Organisation of 2 seminars in Rwenzori to present, explain, and prepare the implementation of the GI certificate (requirements, social organisation and responsibilities, creation of a GI association, etc.).	• URSB published in 2019 official guidelines for GI implementation, covering the various legal aspects of the activity. Hence, we dropped the project activities in the legal domain, to concentrate on the GI development one.
2. IPM strategy for Mt Rwenzori coffee production; climate change impact assessment and	• The "green" performance of Mt Rwenzori CVC and number of SCP practices implemented are enhanced: waste production is	• Compendium on coffee pest and disease control measures in compliance with ECO certification.	• Setup and implement a farm network, all over the Rwenzori area; 35 farms selected (along 6 altitudinal transects) and equipped with automatic microclimate sensors.	• Unexpectedly, the importance of black twig borer on Arabica has been revealed. • Regular surveys are difficult to implement due to logistic constraint.

Outputs	Outcomes	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons Learned
adaptation strategy developed; a GIS system-based, descriptive and dynamic presentation of Mt Rwenzori certified coffee production; publicizing the action and generating optimal conditions for visibility and replication.	reduced, inorganic chemicals are banned.	• IPM and climate change adaptation strategy guidebook. • Pamphlets, factsheets presenting the action. • SWITCH regional conference compendium. • Policy recommendations documents. • Platform implementation.	• P&D dynamic monitoring. Fortnight surveys implemented for main problems: leaf rust, berry borers, antestia bugs. • Data collection is on-going. Analysis should start by the end of 2020, for IPM and Climate Change strategies definition. • Compendium construction initiated (agronomy and P&D domains).	

7.2 Insects for Food, Feed and Other Uses Programme: Results Based Management (RBM) Rolling Framework Report

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
Objective : Promote the utilisation of insects for food, feed, organic waste recycling and pharmaceutical purposes to enhance food security and income generation capacity in sub-Saharan Africa by 2020.				
Specific objective: Develop and promote Insects for Green Economy (GREEiNSECT) by 2018				
1. An appraisal study to document culturally and environmentally acceptable insect species in Kenya conducted.	• Knowledge regarding edible insects in Kenya enhanced.	• Culturally and environmentally acceptable edible insect species in Kenya documented by end of 2014.	• Magara HJO, Tanga CM, Ayieko MA, Copeland RS, Khamis FM, Mohamed SA, Ombura FLO, Niassy S, Subramanian S, Fiaboe KKM, Roos N, Ekesi S, Hugel S. 2019. Performance of newly described native edible cricket *Scapsipedus icipe* (Orthoptera: Gryllidae) on various diets of relevance for farming. Journal of Economic Entomology, 1-12. • Magara HJO, Ayieko MA, Niassy S, Salifu D, Abdelmutalab AGA, Fathiya KM, Subramanian S, Fiaboe KKM, Roos N, Ekesi S, Tanga CM. 2019. Integrating temperature-dependent life table data into insect life cycle model for predicting the potential distribution of *Scapsipedus icipe* Hugel & Tanga. PLoS ONE, 1-27. • Magara HJO, Tanga CM, Ayieko MA, Copeland RS, Khamis FM, Mohamed SA, Ombura FLO, Niassy S, Subramanian S, Fiaboe KKM, Roos N, Ekesi S, Hugel S. (under review). Effectiveness of sampling methods: patterns of edible cricket species richness and diversity associated with three agroecological zones in Kenya. Insect Conservation and Diversity.	• Our findings revealed the impact of diet quality on the biological fitness parameters of *S. icipe*, and the implication of the results are discussed in light of effective mass rearing of this species. • Studies revealed that optimal temperature for mass production of *S. icipe* was 30°C. • Based on a temperature-based model, *S. icipe* is tolerant to a wider range of climatic conditions in Africa. • A total of 18 species of cricket belonging to 3 families (Gryllidae (15 species), Phalangopsidae (two species) and Gryllotalpidae (one species)) have been described from Kenya across 3 agro-ecological zones.
2. The microbiological content of the key edible insects in Kenya (fresh, processed or stored form) identified and analysed.	• Food safety and risk factors associated with edible insects documented.	• The microbiological content of key insects as food in Kenya identified by end of 2017.	• Gatheru JW, Khamis FM, Ombura FLO, Nonoh J, Tanga CM, Maina J, Mohamed SA, Subramanian S, Ekesi S, Fiaboe KKM. 2019. Impact of processing methods on microbial load of reared and wild-caught edible crickets in Kenya. Journal of Insects as Food and Feed 5, 171-183.	• Findings revealed that fresh crickets have higher microbial loads (bacterial and fungal populations) than processed insects. Deep-frying, freeze-drying and snap-freezing were the best processing methods.
3. Potential entomopathogens that pose a threat in the farming of	• Knowledge of entomopathogens that threaten production of edible insects enhanced.	• Potential entomopathogens that pose a threat in the farming of insects documented by end of 2017.	• Out of 14 isolates tested, Kapiti S3 was the most pathogenic among the 3 *M. anisopliae*, recording the highest mortality on the crickets. Caterp B recorded the highest mortality among the *B. bassiana* isolates screened.	• These results demonstrate that crickets are highly susceptible to entomopathogens. Therefore, we must avoid taking them close to colonies.

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
insects profiled and documented.				
4. Molecular characterisation of microbial composition (DNA barcoding and/or RAPD) conducted.	• Information regarding the microbial composition of the edible insects improved.	• Molecular characterisation of microbes attacking edible insects and that pose a threat for food safety conducted by end of 2018.	• A bacterial pathogen that resemble members of the genus *Ricketsiella* was identified in Kenya and Uganda threatening cricket farming.	• In severe cases, insect pathogens may cause the rearing to collapse. Sensitization campaigns to avoid these incidences are currently ongoing.
5. Recommendations for enhancing food safety and quality control of edible insects in Kenya, and for international trade provided.	• Information to enhance policy regulations and legislations governing the use of insects as food and feed available.	• Workshops to provide recommendations to inform policy for development of standards for use of insects as food and feed conducted by end of 2016.	• Currently, draft standards that allows the use of insects and insect products have been completed and are under review in Uganda. A similar process is ongoing Kenya.	
Specific objective: Develop and promote insect feed for poultry and fish production in Kenya and Uganda (INSFEED) by 2018				
1. Socio-economic surveys carried out on the use of insects for feed in poultry and fish farming. 2. Market demand analysis for insects as feed ingredient for poultry and fish conducted. 3. Economic performance of insect-based feed assessed.	• Farmers and feed producers invest more in insect-based feed production and use and increase adoption by 2018.	• At least 3 focus discussions per target country by end of 2015. • At least 500 small-scale farmers surveyed per target country by end of 2015. • At least 100 livestock feed processors surveyed per country by end of 2015. • Comparative costs of at least 3 insect-based feeds assessed by end 2018. • Market demand and cost-benefit analysis conducted for at least one insect-based feed by 2017. • Cost efficiency studies of poultry and fish reared on insect-based feed evaluated by 2018. • Key market segments described by December 2015.	• Macharia JN., Diiro GM, Busienei JR, Munei K, Affognon HD, Ekesi S, Muriithi B, Nakimbugwe D, Tanga CM, Fiaboe KKM. (under review). Gendered analysis of the demand for poultry feed in Kenya. Agrekon.	• The results show that there are substantial gender differences in feed demand and elasticities of feed demand with respect to feed prices.
4. Rearing techniques for key insects suitable for use as feed developed and adapted. 5. Wild harvesting techniques for	• Efficiency improved in insect, poultry and fish rearing for low-cost production and high profit margin by 2018.	• Rearing techniques developed for at least 3 insect species by June 2015. • Safe and cost-effective substrate for rearing of at least 3 insect species documented by end of 2016. • Chemical and microbial toxicity of at least 3 insect species under different rearing techniques profiled by end of 2017.	• Marwa S, Khamis FM, Tanga CM, Fiaboe KKM, Subramanian S, Ekesi S, Van Huis A, Borgemeister C. 2019. Influence of temperature on selected life-history traits of black soldier fly (*Hermetia illucens*) reared on two common urban organic waste streams in Kenya. Animals, 9, 79. doi:10.3390/ani9030079.	• Black soldier fly larvae reared on brewers' spent grain were more efficient and tolerated a wider range of temperatures in comparison with those reared on cow dung. • It is possible to take advantage of the readily available organic waste streams in Kenya to produce nutrient-rich feed from black soldier fly larvae.

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
swarming insects developed and adapted. 6. Chemical and microbial contamination determined, and protocol developed for safe rearing and handling. 7. Nutritive profile of key insects assessed. 8. Insect-based feed formulated and tested.		• Entomopathogens affecting at least 3 insect species colonies documented by 2017. • Wild harvesting techniques developed or adapted for at least 3 species by September 2018. • Effect of trap and postharvest handling on contamination documented by 2017. • Insect based feed formulas developed by 2017. • Nutritive profile of at least 3 insect-based feed assessed by 2016. • Palatability and utilisation rate of at least two insect-based feeds tested on fish and poultry by end of 2017. • Effect of at least two insect-based feeds on fish and poultry growth assessed by end of 2017. • Storage techniques developed for at least 3 insect-based feeds by September 2017.	• Marwa S, Khamis FM, Tanga CM, Fiaboe KKM, Subramanian S, Ekesi S, Van Huis A, Borgemeister C. 2019. The nutritive value of black soldier fly larvae reared on common organic waste streams in Kenya. Scientific Reports 9, 1-14. https://doi.org/10.1038/s41598-019-46603-z. • The potential influence of the rearing substrate on the gut microbial community of black soldier fly has been established. • The techniques for wild harvesting of long-horned grasshoppers have been significantly modified to improve catches and safety of the harvested products for the market in Uganda.	• The results show the potential of black soldier fly to vertically transmit certain bacterial species.
9. Results used to inform policy to support use of insect-based feed in poultry and fish farming.	• Enhance awareness among stakeholders and inform policy by 2017.	• At least two stakeholder workshops held by 2017. • At least 10 media coverage stories on the INSFEED project by December 2017. • At least two policy briefs documented by December 2017. • At least two desk studies and expert interviews conducted per country by 2016. • At least one situation paper on the use of insects for feed produced by June 2018. • Documentation of processed feed leading to national and international standards (Codex) developed by December 2017.	• Documentation submitted to Kenya Wild Service to include edible insects in its policy as domesticated mini-livestock.	
Specific objective: Development and implementation of insect-based products to enhance food and nutritional security in sub-Saharan Africa (EntoNUTRI) by 2019				
1. Insect farming and harvesting techniques for edible saturniids, grasshoppers and crickets developed, and production systems optimised	• Edible insect-based technologies to enhance productivity and consumption of insects as food to improve livelihoods and wellbeing of rural and urban	• At least two improved rearing and two improved harvesting techniques for edible insects developed and disseminated by March 2019. • Field ecology of at least two target edible insects assessed by December 2017. • Wild harvesting techniques for at least 1 target edible insects developed by December 2018.	• Straub P, Tanga CM, Osuga I, Windisch W, Subramanian S. 2019. Experimental feeding studies with crickets and locusts on the use of feed mixtures composed of storable feed materials commonly used in livestock production. Animal Feed Science and Technology 255, 114-215. • Increased understanding of ways of minimizing cannibalism, suitable feeding/oviposition	• New diets produced to replace fresh feed materials, with capacity to improve efficiency and safety of insect production systems. • Internal teamwork and external collaboration are critical for attainment of results. • Studies revealed that vendors in Uganda had poor knowledge of food safety and followed poor hygiene and sanitation practices. All edible grasshopper samples had

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
using locally available substrates. 2. The nutritional attributes of target insect species (fresh, stored and processed) established and appropriate post-harvest technologies for preservation tested and implemented. 3. Food safety (chemical and microbiological) and regulatory requirements to inform policy on the use of insects as food established. 4. Socio-economic assessment – communities' perception of insects as food and the willingness to accept insects as part of their diets as well as the livelihood effects of edible insects in households assessed and documented. 5. Innovations on insect farming and utilization as food transferred to beneficiaries, and R&D capacity and	communities developed and disseminated by March 2019.	• Nutritional attributes of at least 3 edible insects assessed by December 2017. • Improved postharvest handling techniques for at least 2 edible insects developed by December 2018. • At least 2 target edible insects screened for chemical risk factors by December 2018. • Microbial risks associated with 3 target edible insects assessed by March 2019. • At least 2 target country level surveys on community knowledge attitude and practices with edible insects completed by July 2017. • At least 1 survey on consumer willingness to accept edible insects completed by December 2018. • Economic situation of edible insect value chain actors assessed in 1 of the target countries by September 2018. • ToTs on insects to enhance food and nutritional security undertaken for at least 40 stakeholders (20 each for Kenya and Uganda) by December 2018. • Outreach materials (manuals, posters and leaflets) on insect rearing/harvesting/processing/packaging technologies developed and distributed to at least 1,000 beneficiaries in each country by March 2019. • A project website established by March 2016. • Advanced level training of at least 4 PhD and 5 MSc students, especially women, from Africa and Germany accomplished by March 2019.	substrates and developmental biology of the long-horned grasshopper *Ruspolia differens* to boost productivity of its laboratory colonies. • Modified the traditional technique of trapping *R. differens* to improve catch retention, filter non-targets and replace mercury lamps with sustainable and cost-effective light-emitting diode lamps. • Identified trapping sites as critical points of contamination of *R. differens* with potentially harmful microbes, and deep-frying as an effective way of reducing microbial contaminants in the insects to safe levels. • Adapted the use of semio-chemical lures to trap the palm weevil *Rhynchophorus* spp. as a crop protection strategy as well as for collecting the palm weevils for mass production of edible larvae. • Mugo L, Imungi JK, Njue L, Diiro G, Akutse KS, Tanga MC, Khamis F, Subramanian S. (under review). Microbial safety of edible long-horned grasshoppers, *Ruspolia differens* and food hygiene practices among its vendors in Uganda. Journal of Food Safety. • Kusia E, Borgemeister C, Tanga CM, Ekesi S, Subramanian S. (under review). Exploring community knowledge, perception and practices of entomophagy in Kenya. Food Security. • 8 PhD and 3 MSc students trained. • Conducted two training/dissemination workshops with 65 participants (43 males and 22 females).	microbial loads above the legally acceptable microbial limit for ready-to-eat marketed foods. Urgent safety regulations are needed to protect the consumers. • Studies showed that 98.8% of the respondents were familiar with edible saturniids but only 67.1% were pro-active consumers. Though, 73% of the respondents were willing to rear saturniids primarily for income, they cited lack of ready markets as one of the major challenges.

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
entrepreneurship in the field disseminated.				
• **Specific objective: Improving livelihood by increasing livestock production in Africa: An agribusiness model to commercially produce high quality insect-based protein ingredients for chicken, fish and pig industries (ILIPA) by 2019**				
1. Pilot production and demonstration facilities established at *icipe*. 2. Potential scavenging feed resources that can be used as substrate for insect rearing investigated.	• Knowledge regarding practicality of scientific methods based on the availability of these feed resources in Kenya enhanced by 2017.	• Pilot production facility and feed sources for rearing black soldier fly that is culturally and environmentally acceptable in Kenya documented by end of 2017.	• A new large screenhouse (20 x 9 m) pilot facility for black soldier fly production has been installed at *icipe* for training farmers on waste recycling and insect-based protein production. The monthly production potential is 3 tons. • Chia SY, Tanga MC, Osuga I, Ekesi S, Van Loon JJA, Dicke M. 2019. Nutritional composition of black soldier fly larvae feeding on agro-industrial by-products. Entomologia Experimentalis et Applicata (in press).	• Many stakeholders prefer coming to *icipe* for training because of the prototype installed, which they aim to replicate on their farms. • Our findings provide important information to support the use of black soldier fly larval meal as potential new source of nutrient-rich and sustainable **feed ingredients** to substitute the expensive fishmeal and plant sources in animal feed industries.
3. Socio-economic surveys carried out on the use of insects for feed in poultry, fish and pig farming. 4. Market demand analysis for insects as feed ingredient for poultry, fish and conducted.	• Farmers and feed producers invest more in insect-based feed production and use, and increase adoption by 2019.	• At least 500 small-scale farmers surveyed by end of 2017. • Comparative costs of at least 1 insect-based feed assessed by end 2017. • Market demand and cost-benefit analysis conducted for at least one insect-based feed by 2018.	• Chia SY, Tanga CM, Van Loon JJA, Dicke M. 2019. Insects for sustainable animal feed: inclusive business models involving smallholder farmers. Current Opinion in Environmental Sustainability 41, 23-30. • Chia SY, Macharia J, Diiro GM, Kassie M, Ekesi E, Van Loon JJA, Dicke M, Tanga CM. (under review). Smallholder farmers' knowledge and willingness to pay for insect-based feeds in Kenya. PLoS ONE.	• With low initial capital investments, smallholder insect farmers have good opportunities to increase productivity, improve their livelihood and contribute to food security and a circular economy. • Over 70% and 80% of poultry and fish farmers, respectively, are aware that insects can be used as a feed ingredient. In addition, over 60% and 75% of poultry and fish farmers, respectively, consider insects as a good component of feed.
5. Awareness on the potential of insect-based feeds for poultry, pig and fish farming raised.	• Farmers consider insects as an alternative source of feed for poultry, pig and fish farm enterprises by 2018.	• At least 10 awareness stakeholders meeting organized by 2018. • 5 radio spots realized by 2018. • At least 30% of farmers attending awareness meetings consider insect as an alternative source of feed for poultry, pig and fish farm enterprises by 2018.	• Gérard D, Copeland RS, Tanga CM. 2019. Description of *Eniacomorpha hermetiae* Delvare sp. n. (Hymenoptera, Chalcidoidea, Chalcididae) a pupal parasitoid of *Hermetia illucens* (L.) (Diptera, Stratiomyidae), and a potential threat to mass production of the fly as a feed supplement for domestic animals. Zootaxa 4638, 237-254.	• New pupal parasitoid identified as potential threat to mass production of the black soldier fly as a feed supplement for domestic animals.
6. Capacity of youth and women farmers (small-scale and commercial) in mass-production,	• Youth and women farmers (small-scale and small commercial) engage in mass-production, harvesting and primary	• At least 10 youth and 10 women groups trained in mass-production, harvesting and primary processing of black soldier fly protein by 2018. • At least 30% of the group members produce, harvest and process black soldier fly by 2019.	• Through an incubation program implemented at *icipe*, an additional 384 new farmers (126 females and 258 males) have been trained.	• Women and youth are showing great interest in insect farming technologies.

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
harvesting and primary processing of black soldier fly protein built.	processing of black soldier fly by 2019.			
7. Formulations for nutritious insect-based feeds for poultry, pigs and fish established and tested.	• Nutritious insect-based feed formulation for poultry, pigs and fish ready for release for mass-production by 2018.	• At least one formulation for insect-based feeds for poultry, pigs and fish established and tested by 2017. • At least two commercial small-scale feed companies willing to take nutritious insect-based feed formulation for mass production by 2019.	Chia SY, Tanga CM, Osuga IM, Alaru AO, Mwangi DM, Githinji M, Subramanian S, Fiaboe KKM, Ekesi, Van Loon JJA, Dicke M. 2019. Effect of dietary replacement of fishmeal by insect meal on growth performance, blood profiles and economics of growing pigs in Kenya. Animals, 9, 705. doi:10.3390/ani9100705. Sumbule EK, Osuga IM, Ambula MK, Miano DM, Alaru PAO, Githinji M, Subramanian S, Fiaboe KKM, Niassy S, Dubois T, Khamis FM, Ekesi S, Van Loon JJA, Dicke M, Tanga CM. (under review). Replacing fishmeal with black soldier fly larval meal in exotic ISA brown commercial layer chicken diets: implications on feed intake, growth, carcass quality and profitability. Poultry Science. 4 small-scale feed processors (Treasure Feeds Ltd, Macden Animal Feeds Ltd, GAF Feeds Ltd and Josiche General Traders Ltd) have used the protocol for poultry and pig feed formulation.	• Results show that black soldier fly meal is a suitable and cost-effective alternative to fishmeal in pig feeds. • Results demonstrate that insect nutrient-rich balanced diets have potential of being utilized as commercial feeds for improved and cost-effective large-scale production of layer chicks and grower pullets in the poultry industry.
8. Insect based feed tested for microbial pathogens and toxins.	• Insect-based feed formulation free from microbial pathogens and toxins ready for release for mass production by 2018.	• At least 1 feed formulation is tested free from microbial pathogens and toxins, and can be proposed for mass-production by 2018. • At least two commercial small-scale feed companies willing to take safe insect-based feed formulation for mass production by 2019.	• Khamis FM, Ombura FLO, Akutse KS, Subramanian S, Mohamed SA, Fiaboe KKM, Saijuntha W, Van Loon JJA, Dicke M, Dubois T, Ekesi S, Tanga CM. (under review). Insights on the global genetics and gut microbiomes of black soldier fly, *Hermetia illucens*. Microorganism.	• There are slight phylogeographic variabilities between black soldier fly populations across the globe. • 16S data depicted larval gut bacterial families with economically important genera that might pose health risk to animals.
9. Protocols and tools for production of safe insect-based feeds for poultry, pigs and fish in the prospect of certification developed.	• Protocol and tool for production of safe insect-based feeds used by small-scale feed processors by 2018.	• At least 1 protocol and tool for production of safe insect-based feeds available by 2018. • At least 2 small-scale feed processors use the protocol and tools for feed formulation by 2019.	• Protocol for the safe production of insect-based feeds has been established and has been made available to feed millers.	• On-farm trials with insect-based feeds from millers has showed positive results and interest from farmers.

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
10. Youth and women farmer groups linked to profitable markets (e.g. feed companies) for the insect-based protein products.	• New sector for employment, value chain for insect protein created in Kenya by 2019.	• At least 10 youth groups and 10 women groups linked to profitable markets for insect-based feeds by 2018. • At least 20% of the farmer group members are selling insects to small-scale feed processors by 2019.	• Over 37 new insect-based entreprises and cost-effectiveness of each modular systems established. • A total of 53 farmer groups (22 youth and 31 women groups) have been recruited, trained and provided with starter kits for black soldier fly production. Farmer groups have been taught to carry out effective sun drying of their larvae.	• Scaling up insect production, especially black soldier fly, is relatively easy with little investment.
Specific objective: INSect-based agriBIZiness for sustainable grasshopper and cricket production and processing for food in Kenya and Uganda (INSBIZ) by 2020				
1. Market potential and market performance of insect-based food products assessed.	• Informed investment in insect-based food product commercialization increased by 2020.	• 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.	• Assessing the market size and testing the market performance of insect-based foods has been completed in Uganda with advance insights into the profitability of the venture. • Value chain mapping of long-horned grasshoppers in Uganda has been completed.	• Despite the underdeveloped value chain, edible insects still constitute an important economic sector.
2. Mass rearing protocols for crickets and grasshoppers adapted, piloted and upscaled.	• Safe protocols for cricket and grasshopper rearing established and widely adopted at various scales by 2019.	• 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 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.	• Mass production facilities on-farm (using screenhouses) for crickets rearing has been established by Treasure Feeds Ltd in collaboration with InsectiPro Ltd (Kenya) and Agrarian Systems (Uganda). • Production technologies for mass rearing the long-horned grasshopper under laboratory conditions have been established in Kenya and Uganda. • The optimized rearing protocol has been implemented to significantly reduce cannibalism to less than 5% using an artificial diet.	• Despite the high cannibalism observed in *R. differens* colonies, now there is great promise to scale out production to farm fields with the new technologies developed.
3. Ready-to-eat whole insects, insect flours for use	• Adoption and use of insect-based food standards in Kenya	• At least two food-based SMEs produce and commercialize insect-based food by 2019.	• Ready-to-eat products such cookies, extruded snacks (Krickies) and porridge flour has been developed in Kenya and Uganda.	• Based on the market feedback combined with that of an evaluation panel (consisting of processors, consumers

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
as ingredients in food preparation developed and characterized, and insect-enriched porridge flours and cookies processed.	and Uganda, and increased consumer confidence in insect-based products by 2020.	• 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 5-year-old children or below developed and commercialized by 2019. • Insect-based novel food available on supermarket shelves by 2020.	• Currently, grasshopper products are being marketed/sold in the food parlour of the Food Technology and Business Incubation Centre of Makerere University. • Murugu DK, Onyango AN, Ndiritu AK, Osuga IM, Chesoto X, Fiaboe KKM, Ekesi S, Nakimbugwe D, Tanga CM. (under review). Exploring edible crickets *Scapsipedus icipe* and *Gryllus bimaculatus* as novel source of food ingredients. Journal of Scientific Reports. • Murugu DK, Onyango AN, Ndiritu AK, Tanga CM, Osuga IM, Fiaboe KKM, Ekesi S. (under review). Fat quality and phytochemical composition of farmed cricket species in Kenya. • Kipkoech KC, Kinyuru JN, Imathiu S, Rochow VBM, Roos N, Tanga CM. (under review). *In Vitro* bactericidal effects of chitosan extracted from edible crickets combined with probiotic bacteria against *Salmonella typhi.* Pathogens.	and marketers), the products have been greatly improved. • Our findings demonstrate that *S. icipe* and *G. bimaculatus* can sufficiently provide the daily required nutrient intake for improved human nutrition. Therefore, integration of crickets into ready-to-eat preparations will significantly reduce insect food neophobia. • Chitosans from crickets are very effective antimicrobial agents against *Salmonella typhi.*
4. Favourable enabling environment for insect-based food through policy, advocacy and awareness creation established.	• High consumer acceptability for insect-based products in Kenya and Uganda by 2020.	• 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. • 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.	• Cheseto X., Baleba SBS, Tanga CM, Kelemu S, Torto B. (under review). Chemistry, sensory characterization and consumer perception of bakery products prepared with oils from African edible insects. Journal of Food Quality and Preference. • Currently, the draft standards and policy document that allows the use of insects and insect products for humans has been completed and reviewed in Uganda, while that in Kenya has been initiated.	• The oil composition of *R. differens* is significantly rich in omega-3 fatty acids, flavonoids and vitamin E. • Consumers' acceptability of 95% was recorded for cookies prepared with *R. differens*, while the willingness-to-pay (WTP) for bakery products is 7 times higher compared to that of olive oil.
Specific objective: Testing business models for scaling insect-based protein feed for use in poultry farming and aquaculture in Kenya (SiPFeed)				
1. Markets and marketing channels for insect-based protein feed using	• Identify and adapt potential business models for insect-based protein for feed	• Cost-effective and suitable commercial models identified and adapted for use of insects as feed enhanced by 2020.	• Zewdu A., Diiro G, Tanga CM, Beesigamukama D, Kassie M. (under review). Socio-economic and environmental implications of replacing	• Results indicate that replacing 5-15% of soybean meal and fishmeal by black soldier fly larval meal in the commercial poultry industry alone would increase Kenya's annual gross domestic product by 0.02-0.05%

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
different business models developed.	in poultry and fish production by 2019. • Map the potential insect-based protein feed supply chains by 2019. • Establish and monitor the linkages between insect-based protein feed value chain actors by 2020. • Work with the private sector partners to support various components, including training, financing and awareness creation by 2020. • Develop insect-based protein feed production and marketing information exchange platform to link actors along the value chain by 2020.	• Supply chains model (e.g. rearing substrates, equipment) for commercial production of insects documented by 2019. • Out-grower models utilising insect for feed by farmers and private sectors established by 2020. • Private sector feed millers subcontract entrepreneurs and contribute to the training and awareness campaigns of black soldier fly production by 2020. • Pre-financing for different needs in the production system (e.g., drying and storage equipment) documented by 2020. • SMEs develop outgrower models for sourcing insects from farmers/cooperatives and established market linkages with feed processors by 2020.	conventional poultry feed with insect-based feed in Kenya. Global Environmental Change. • A stakeholder workshop was organized with 25 participants representing different sectors of the value chain to develop a value chain map of the insects-for-feed sector and identify the strength, weaknesses, opportunities and threats (SWOT) across the main value chain actors to inform project activities. • Black soldier fly production has been sufficiently boosted and farmers have been supplied with stock populations for initiation of their own production systems. • Baseline survey of 464 farmers confirmed high willingness of livestock farmers to use insect-based feed in their poultry and fish production. 93% of male and 98% of female farmers are willing to use insect-based feed, if safety and policy support were in place. Similarly, 85% of feed producers showed interest to integrate insects into their feed formulations to partially or totally substitute protein from other sources like fishmeal or soya. • Easy-to-use manuals, WhatsApp group and on-line mobile interactive platform (DuduTalk) for black soldier fly farmers has been developed.	(US$ 12-35 million). It would contribute to a reduction in the number of poor people (i.e., those below the official poverty line) by 0.05-0.16 million. • However, some gender-based differences are evident, particularly for awareness of insect farming, which is about one-third and 57% for women and men respondents, respectively. • Women showed a large interest in insect production.
2. Transfer and promote insect-based protein feed technologies among the various actors along the value chain.	• Establish black soldier fly rearing facilities for demonstration and training on best practices related to production, processing and packaging by 2019. • Provide starter kits for production of insect-based protein by 2019. • Develop and disseminate, production protocols, training and outreach materials to sensitize	• Simple and cheap mass production technology with high potential for scale at the farm and SME levels established by 2020. • The most effective technologies for different commercial models documented by 2019. • The constraints/challenges of black soldier fly production and options/challenges documented by 2020. • At least 200 entrepreneurs and start-ups have access to proven low-cost technologies by 2020. • At least 200 farmers adopt the technology of mass production of black soldier fly for feed on-farm by 2020.	• Currently, over 52 new medium-scale insect-based enterprises and 278 (73.3% males and 26.7% females) smallholder farmer enterprises have been established in the target project sites. The production levels of the medium-scale enterprises stands at 0.4 t fresh black soldier fly larvae per week. • 26 small-scale feed millers are willing to take up processing insects into proteins for use as ingredients in poultry feed formulation. • The identification of a new pupal pathogen, the phoretic mite *M. muscae domesticae*, and the susceptibility of black soldier fly to entomopathogens remain a key constraint to on-farm production.	• More adoption and willingness to be trained has been recorded. • Field millers are willing to use insect meals, provided the volume of black soldier fly is available for regular supply when needed. • New control measures are required to mitigate the impact of natural enemies.

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
	and create awareness on insect-based protein feed by 2020. • ToT workshops on all aspects of the project outputs by 2020.		• 28 poultry, fish and pig farmers, and 4 extension officers were trained on all aspects related to the project outputs.	
3. Evidence-based data to support scaling and adoption of insect-based protein feed enterprises generated.	• Establish baseline and end-line data by 2020. • Optimize modular insect production systems for scaling, based on stakeholder feedback and monitor for product quality and safety by 2020. • Assess the household level socioeconomic benefits of insect-based protein feed farming and formulation among millers and farmers in the poultry and aquaculture industry by 2020. • Assess the potential for employment generation and country level economic benefits of insect-based protein feed for poultry farming in Kenya by 2020.	• At least develop a business case for production of insect for feeds via the different model (farmers and SME developed) and make recommendation on the most viable business models by 2020. • Develop and distribute easy to use manual for setting up of successful insect farming with details on costing by 2020. • At least 2500 metric tonnes of insect-based protein produced and utilised for on-farm trails by 2020. • At least 3 optimal facilities for effectively scaling out on-farm production of black soldier fly established by 2020. • The nutritional and safety qualities of black soldier fly reared on various substrates under different production models compared to laboratory-reared black soldier fly documented by 2020. • 200 farmers recruited to participate in on-farm assessment and performance of insect-based protein feed on poultry and fish in target locations by 2020. • 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 by 2020. • Establish the socio-economic benefits of insect-based protein farming and feed formulation in poultry and aquaculture production by 2020. • Establish the viability of insect-based protein enterprises for job creation among youths and women by 2020.	• Maina AN, Osuga IM, Munga LK, Munguti JM, Subramanian S, Fiaboe KKM, Van Loon JJA, Dicke M, Ekesi S, Tanga, CM. (under review). Performance and carcass characteristics of the African catfish (*Clarias gariepinus)* reared on diets containing black soldier fly (*Hermetia illucens*) larvae meal. Aquaculture. • Mwangi J, Kinyuru J, Kahenya P, Osuga IM, Subramanian S, Ekesi S, Van Loon JJA, Dicke M, Tanga CM. (under review). Sensory characteristics of eggs produced by exotic Isa Brown chicken fed on a diet supplemented with black soldier fly larval meal. Journal of Insects as Food and Feed. • Mapping of the insect feed value chain and identification of challenges and opportunities was carried out with 25 stakeholders. • 7 commonly available substrate recipes for rearing black soldier fly have been developed for on-farm production, with crude protein content of 40.5-63.8%. • Studies demonstrated that a 5-15% replacement of fishmeal with black soldier fly meal has the potential to generate new employment for 700-2,000 people per year in Kenya.	• Black soldier fly larval meal can partially replace fishmeal in diets for African catfish to improve growth and production.
Specific objective: INSFEED2: Insect feed for poultry, fish and pig production in Sub-Saharan Africa- Phase 2 by 2021				

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
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 2019. • The long-term potential impact of insect-based feed technologies on food and nutritional security predicted by 2019. • Economic viability of insect-based feed supply chain models to guide scaling up pathways by 2020.	• Two scientific papers on efficient insect mass rearing techniques as affected by different agro-ecological zones. • One training guide on insect mass-rearing for feed with reference to production scales and gender developed. • 3 scientific publications on cost-effective organic fertiliser 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. • 2 Msc and 1 PhD student trained.	• The cost-effectiveness and potential livelihood effects of insect-based feed technologies in Kiambu county has been assessed using 370 households. • Macro-economic studies showed that adopting black soldier fly larval meal by 5-15% can increase foreign currency savings by US$ 1-3 million and employment by 3,300-10, 000 people per year.	• The surveys confirm high willingness of livestock farmers to use insect-based feed in their poultry and fish production (93% and 98% of male and female farmers, respectively). Also, 85% of feed producers are interested in integrating insects into their feed formulations to partially or totally to substitute fishmeal or soyabean. • At least a 5% adoption of black soldier fly meal by the commercial poultry industry would benefit the society by recycling bio-waste equivalent to 57% every year in Nairobi, Kenya.
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 fertiliser.	• Traceability and capacity planning for reliable and timely meeting of customers' demands improved by 2021. • Quality organic fertilizer alongside high yielding insect production developed by 2020. • 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 2021.	• Report on existing supply chain models for key commodities in Kenya and the role of the youth, women and men in feed supply chain produced. • Paper 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. • Paper 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.	• Sumbule EK, Ambula MK, Osuga IM, Miano DM, Alaru PAO, Mithinji M, Subramanian S, Ekesi S, Van Loon JJA, Dicke M, Tanga CM. (under review). Recycling of agro-industrial waste to *Hermetia illucens* larval meal for chicken layer feeds: implications on egg production, egg quality and profitability. Poultry Science. • Beesigamukama D., B. Mochoge B, N.K. Korir NK, K.K.M. Fiaboe KKM, D. Nakimbugwe D, Khamis FM, Subramanian S, Wangu MM, Dubois T, Ekesi S, Tanga CM. (under review). Low-cost technology for recycling agro-industrial waste into nutrient-rich organic fertilizer using black soldier fly. Waste management Journal. • Beesigamukama D, Mochoge B, Korir NK, Fiaboe KKM, Nakimbugwe D, Khamis FM, Subramanian S, Wangu MM, Dubois T, Ekesi S, Tanga CM. (under review). Black soldier fly for effective agro-industrial waste recycling and recovery of high larval biomass and quality frass fertilizer. Journal of Cleaner Production. • Mawai H, Nabikyu J, Diiro GM, Muriithi BW, Irungu P, Mburu J, Van Loon JJA, Kassie M, Dicke M,	• *Hermetia illucens* larvae meal is a suitable substitute for fish meal in the diet of Isa Brown laying hens. • The amendment of substrate with sawdust to C/N ratio of 15 could generate compost with desirable nutrients for use as high-quality fertilizer for organic farming. • The initial composting of biochar amended feedstocks using black soldier fly larvae can significantly shorten compost maturity time to 5 weeks with enhanced nutrient recycling for organic farming. • There is high consumers' acceptability and willingness to pay for meat from chicken-fed insect-based feeds. Thus, meat products from chicken-fed insect-based feeds are likely to command a substantial premium at retail outlets.

Outputs	Outcome	Performance Indicators	2019 Progress made in achieving the outcomes	2019 Lessons learned
			Ekesi S, Tanga CM. (under review). Consumer preferences and willingness to pay for meat derived from chicken fed on insect-based feeds. Food Policy.	
3. Develop and test gender-inclusive insect feed supply models and build capacity along the value chain.	• Awareness creation conducted by 2019. • Develop, test and compare different supply chain models linking insect production with feed manufacturing by 2020.	• 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 use in animal feed developed. • At least 3,000 youth, men and women trained in the different target groups. • 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 held.	• Using the Pro-WEAI survey tool, our results show that 60%, 41%, and 56 % of women householders, wives in men-headed households and men-headed households, respectively, were empowered. For most of the empowerment indicators, differences across groups were not significant, except that male farmers had higher self-efficacy than female farmers, and wives had lower work-life balance than others. • Currently, a WhatsApp group of black soldier fly farmers has been established and is operational with interested persons already communicating their challenges and marketing of their insects. • An insect farming communication program feedback system called DuduTalk (online platform) that allows *icipe* to capture all incoming and outgoing communication through telephone calls and text messages (SMS) in real-time has been initiated. • An easy-to-use manual for setting up successful insect farming enterprises of different scales of operation is near completion.	• High empowerment of women-headed households was observed. • Lots of insect farmers are connected in the platform and have endorsed the benefits of grouping for a common purpose.

7.3 Animal Health Theme: Results Based Management (RBM) Rolling Framework Report

Outputs	Outcome	Performance Indicator	2019 Progress made in achieving the outcomes	2019 Lessons Learned
Objective: To develop attractive and effective killing and repellent system for control of vectors of camel trypanosomosis (surra) and to reduce vector and disease levels by 50% by 2020.				
1. At least one potential control technology developed for vectors of surra.	• At least one olfactory bait and one repellent blend tested and available for control of vectors of surra.	• At least 50% decrease in flies attracted to camels. • At least 50% decrease in disease incidence. • Favourable assessments by participating livestock keepers and veterinary staff. • Publications produced.	• The integrated surra vectors management, composed of repellent (camel-collar) and attractant developed and tested. • The technology demonstrated efficacy for limiting contact between biting flies and camels, demonstrated by improved camel health (rising blood packed cell volume (PCV)) and reduced number of infected camels.	• We need to improve the wooden collar, especially finding more durable rope. • Dispenser optimization, to make it more durable without compromising its efficacy.
Objective: To upscale and adapt tsetse repellent technology in partnership with the private sector and to reduce trypanosomosis risk by 50% by 2020				
1. Repellents for control of vectors of human sleeping sickness evaluated.	• Synthetic and waterbuck repellent blend evaluated for *Glossina fuscipes fuscipes* in Kenya.	• -At least two tsetse repellent blends evaluated for control of vectors of human sleeping sickness, *Glossina fuscipes fuscipes* • At least 50% decrease in fly catches in presence of repellents. • No. of trials undertaken. • Publications produced.	• Three (3) trials are ongoing for the tsetse repellents in several sites in Kenya and Zambia. • Collaborations for upscaling have been established relevant governmental bodies: In Ethiopia with the (1) National Institute for the Control and Eradication of Tsetse and Trypanosomosis (NICETT) and the (2) Ministry of Livestock and fisheries in Ethiopia, and (3) Tsetse and Trypanosomiasis control unit in Zambia. • Evaluation of repellents against *G. fuscipes fuscipes* have been completed and published. Njelembo JM et al (2019). (https://doi.org/10.1371/journal.pntd.0007510	• Need to further optimize repellents for vectors of sleeping sickness. All blend variations tested show an efficacy of <35%. This can be further improved for effectiveness against the vectors.
2. Integrated use of repellents with traps and screens, and olfactory baits evaluated in push–pull strategies to stop flies reinvading areas where they have been controlled.	• Effective barrier system developed to stop flies from reinvading tsetse-controlled areas.	• Complementary technologies identified with potential for integration with repellent technology to stop reinvasion. • Barrier prevents at least 80% flies from entering a controlled area.	• Evaluation on-going for a novel barrier in the interface of the Shimba Hills National Reserve (SHNR), Kenya. This is implemented in collaboration with the County government, the Kenya wildlife services and local community-based organizations. • The candidate barrier is designed to use 20% of the recommended number of traps for tsetse control and could improve cost-effectiveness of control many-fold.	• Need to sensitize and train national and local systems on integrated tsetse control with trap barriers.

Outputs	Outcome	Performance Indicator	2019 Progress made in achieving the outcomes	2019 Lessons Learned
3. Technology for large-scale production of dispensers and repellent compounds passed over to private sector.	• At least one agreement signed with entrepreneurs for further improvement of the dispensers for commercialization of tsetse repellent technology • At least one local entrepreneur identified for manufacturing/ • distribution of repellent collars.	• No. of agreements signed. • No. of meetings held. • At least one design prototype tested for upscaling.	• Agreement and license for mass producing and distributing the repellent technology signed with INNOVA biologicals LTD. • More than 5,000 repellent collar units produced in 2019/2020 and made available for distribution through INNOVA. • The cost of the repellent collars reduced to US$3. The collar is re-charged with an easy-to-handle refill sachet that costs $1 per month.	• Need to de-risk and provide scientific backstopping for private partners and the technology.
3.1. Business plan for commercialization, packaging, product registration, marketing and dissemination for rollout of the technology developed 3.2. Advocacy of the repellent technology enhanced.	• Business plan developed for commercialization, dissemination, registration and roll out. • • Advocacy of repellent technology enhanced in collaboration with stakeholders.	• Business plan developed. • At least one P-P-P partner using the business plan. • At least 3 advocacy events undertaken.	• Following a progressive business plan developed with mHealth Kenya, an ICT platform (LiMA) has been developed that enabled a seamless link between farmers and the producer and distributor for the repellent technology. • With 60 community-owned resource persons trained on the use of LiMA, the local capacity for tsetse control has been improved considerably. • A cashless payment platform is currently under development in LiMA before it is scaled out. • Sensitization and training meetings implemented in Benshangul-gumuz region of Ethiopia for 20 veterinary officers and health workers from the Ministry of Agriculture and Fisheries. • Several presentations about the technology were made in multiple international scientific and veterinary meetings including: (1) the International Scientific Council for Trypanosomiasis Research and Control (ISCTRC), and the (2) AU-PATTEC meetings in (Abuja, Nigeria), the World Association for the Advancement in Veterinary Parasitology (Madison, USA), at the veterinary insect workers conference (San Juan, Puerto	• Need to integrate the distribution of the repellent technology with other pest control technologies.

Outputs	Outcome	Performance Indicator	2019 Progress made in achieving the outcomes	2019 Lessons Learned
			Rico).	
4. Integrated validation trials in Shimba Hills upscaled in partnership with the local county staff of the Ministry of Agriculture and Fisheries in Kwale and KWS, and impact on disease levels and drug use and animal productivity assessed.	• Tsetse repellent technology adapted, up-scaled and integrated with other tsetse and disease control tactics for sustainable trypanosomosis control in Kenya.	• Disease reduced by > 50%. • Incidence of tsetse populations reduced >50%. • Drug use reduced >50%. • At least 3000 households use repellent technology.	• Trials for validation in Shimba Hills showed that the repellent technology reduces the incidence of AAT in cattle by more than 80%, the use of trypanocides by 60% whilst increasing cattle ownership by 72.7%. Oxen showed enhance traction power ploughing 60% more land and leading to an increment of land under cultivation by 73.4%. Adopting farmers reduced by 69.1% the acreage trilled by hand. Saini et al 2017: https://doi.org/10.1371/journal.pntd.0005977. • About 4068 farmers have benefitted directly from the up-scaling action (1346 female, 2722 male) with approximately 192,000 indirect beneficiaries (78,720 female, 113,280 male). • Upscaling of the technology is now led by INNOVA Biologicals LTD.	• Livestock keeping in this mixed farming community plays many roles. There is need for a comprehensive study to attribute costs and benefits of integrating repellent technology in disease management.
5. Socio-economic impact of the repellent technology assessed.	• Awareness created and socio-economic impact of the tsetse repellent products documented.	• At least 3 stakeholder trainings held. • At least 3 awareness creation workshops held for local government departments and other stakeholders. • Socio-economic impact study conducted. • *Ex-ante* and *ex-post* financial, socio- and economic impact assessments.	• *Ex-ante* socio-economic impact study implemented in Shimba Hills. The data are currently being analysed.	
Objective:- A novel ticks management strategy that is based on the use of bioacaricide, semiochemicals and/or botanical, developed and implemented by 2020.				
1. A joint committee (*icipe* and Real IPM) responsible for project implementation and monitoring of activities	• A novel ticks management strategy based on the use of bioacaricide, semiochemicals	• At least 20 fungal isolates screened for virulence to at least two important tick species.	• Application for large scale Randomized Control Trial (RCT) submitted to the Veterinary Medicines Board (VMD) in Kenya. • One isolate produced by Private sector.	• Sufficient time (~12 months) should be planned for product licensing, and authorization for field testing.

Outputs	Outcome	Performance Indicator	2019 Progress made in achieving the outcomes	2019 Lessons Learned
established. 2. Novel ticks product (bioacaricide) market survey expanded to Tanzania and completed. 3. A business plan to bring novel ticks control product into market developed	and/or botanical developed and implemented by 2021.	• At least 3 isolates identified and their compatibility with semiochemicals, botanicals and synthetic acaricides completed. • A resistance management package for one synthetic acaricide developed. • One large-scale field efficacy trial completed by 2015 for the combination of the most promising individual components.	• Combined control project for ticks and tsetse flies launched (with funding from BMZ). • Survey for tick diversity and abundance undertaken in Kenya (Homa Bay, Marsabit, Kwale & Kilifi counties) and Ethiopia (Benshangul Gumuz region). • Publication: Kidambasi et al (2019) *AAS Open Res* 2:164 (https://doi.org/10.12688/aasopenres.13021.1).	
Objective:. Developing a new strategy of trypanosome transmission blocking by enhancing trapping of trypanosome-infected tsetse flies by 2019				
1. Investigate the impact of trypanosomes on host animal semio-chemicals change 2. To study the response of trypanosome positive biting flies to trypanosome induced semio-chemicals 3. To use trypanosome induced semio-chemicals for trypanosome diagnosis lure that is biased towards trypanosomes infected *G. pallidipes* developed for trypanosomes transmission blocking.	• Trypanosome induced semio-chemicals identified • Semio-chemicals that are more attractive to trypanosome infected flies identified • Chemical markers for trypanosome diagnosis identified • Simple trypanosome diagnosis tool developed • The name and components of the lure identified. Furthermore, the best dispenser optimized.	• At least 50% decrease in flies attracted to camels. • At least 50% decrease in disease incidence. • Favourable assessments by participating livestock keepers and veterinary staff. • Publications produced. • Number of trypanosomes positive *G. pallidipes* attracted per trap.	• Cow urine from *T. congolense* positive cow attracted more trypanosome infected tsetse flies (*G. pallidipes*) under field conditions, as compared to urine from trypanosome negative cows. • Potential demonstrated for 'transmission blocking' by selective trapping of infected tsetse flies.	• At the moment we are trying different blend composition and ratio to mimic the trypanosome infected cow urine chemically so that we can use to attract more infected tsetse flies to block animal trypanosomiasis transmission.

7.4 Human Health Theme: Results Based Management (RBM) Rolling Framework Report

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
Objective: Contribute towards malaria elimination through the development of effective vector control strategies and public health initiatives by 2020.				
Comprehensive evaluation of icipe's ongoing integrated vector management (IVM) sub-projects.	• At least two new proposals to mobilise funding for strengthening IVM research and capacity-building in eastern and southern Africa developed by 2016 • An additional two new IVM projects in Kenya and Ethiopia developed by 2019	• Regular evaluation reports of ICIPE IVM projects in Kenya and Ethiopia • New IVM proposal documents.	• External evaluation of IVM work carried out by *icipe* in Kenya and Ethiopia from 2016-2018 was successfully conducted in April/May 2019 and the report approved by Biovision Foundation, the main donor of the IVM work in the eastern African countries. • WHO-AFRO and *icipe* signed a Technical Service Agreement (TSA) in 2018 for an initial 4 disbursements of funds to *icipe* with a total amount of US$838,311, for the period 11 July 2018 – 31 July 2019. Negotiations for release of the remaining funds to cover the period August 2019 – June 2022 got underway during the reporting period. • New funding for malaria IVM secured by *icipe* from NORAD in 2018 continued, focused on the continuation of IVM research and capacity building activities in Ethiopia for the period 2018-2022.	• *icipe* is steadily expanding its reach related to human health research and capacity building in eastern and southern African countries striving for malaria elimination. • Implementation of the current IVM projects is enabling *icipe* to leverage more funding for malaria from the Global Environment Facility (GEF) and other donors, including NORAD.
Implementation of integrated vector management (IVM) promoted to improve health and livelihoods of communities in malaria-affected areas of Kenya and Ethiopia.	• At least 60% increased awareness among communities on IVM strategies for vector-borne disease control by 2018. • Adoption of IVM policy for malaria control by the Ministry of Health (Kenya) and Ethiopia by 2017. • At least 60% decrease in malaria prevalence and mosquito densities in target areas by 2018.	• Number of community members trained. • Number of combinations of vector control methods (non-chemical/chemical) being used at community level. • Availability of an IVM decision-making tool for policy makers and vector control personnel. • Number of IVM workshops for policy makers and other key stakeholders. • Levels of malaria prevalence and mosquito relative density. • Improvement in socio-economic status of households. • Number of articles published in peer reviewed journals.	• **Product development:** • UZIMAX, an environmentally safe plant-based biopesticide developed by *icipe* for control of larvae of malaria vectors, was registered by the Pest Control Products Board (PCPB) for use in Kenya. This was a significant achievement considering the scarcity of safe and effective larvicides for mosquito control globally. • **Publications:** • Progress with publication of manuscripts from work in Kenya and Ethiopia was as follows during the reporting period:	• Implementation and sustainability of IVM requires continuous engagement of key stakeholders, most notably the community, national programmes for vector and vector-borne disease control, research institutes such as *icipe* and donors interested in promoting health research.

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
			• **Published:** • Asale A, Kussa D, Girma M, Mbogo C, Mutero, CM (2019). Community based integrated vector management for malaria control: Lessons from three years' experience (2016-2018) in Botor-Tolay district, Southwestern Ethiopia. *BMC Public Health* 19:1318. • Ng'ang'a PN, Mutunga J, Oliech O, Mutero CM (2019). Community knowledge and perceptions on malaria prevention and house screening in Nyabondo, Western Kenya. *BMC Public Health* 19: 423. • Kibe LW, Habluetzel A, Kamau A, Gachigi JK, Mwangangi J, Mutero CM, Mbogo CM (2019). Low awareness and misconceptions of immature mosquito stages hinders community participation in integrated vector management in Malindi, Kenya. *Journal of Public Health and Diseases.* 2(1): 7-17. • **Submitted** • Mutero CM, Okoyo C, Girma M, Mwangangi J, Kibe L, Ng'ang'a P, Kussa D, Diiro G, Affognon H, Mbogo CM. Evaluating the impact of larviciding with *Bti* and community education and mobilization as supplementary integrated vector management interventions for malaria control in Kenya and Ethiopia (Submitted September 2019). • Diiro GM, Kassie M, Muriithi B, Gathogo N, Kidoido M, Bwire J, Marubu R, Mutero C. Willingness to pay for community-based malaria vector control: An auction experiment of mosquito larviciding using biopesticides in Kenya (submitted Nov 2019).	

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
			• Ng'ang'a PN, Okoyo C, Mbogo C, Mutero CM. Evaluating effectiveness of screening house eaves as an intervention for integrated vector management for malaria control in a rural area of Western Kenya (Submitted Nov 2019). • Ochola, JB, Mutero CM, Marubu R, Moreka L, Haller BF, Hassanali A, Lwande W. Mosquito larvicidal activity of *Ocimum kilimandscharicum* essential oil and its water-miscible formulation under laboratory and semi-field conditions. *Chemoecology (Submitted 2019).*	
Regional and national IVM capacity strengthening for control of malaria and other vector-borne diseases expanded in eastern and southern Africa	• At least 20 staff of national malaria control programmes of Ethiopia, Madagascar and Eritrea trained in IVM in 2016. • *icipe's* role as a regional hub for participatory IVM training in Africa is significantly enhanced from 2016 onwards as a result of increased collaboration with key partners including WHO-AFRO, UNEP, GEF, Stockholm Convention, and Biovision. • IVM training of at least 100 program staff of southern Africa countries dependent on DDT for malaria control achieved by 2019	• Ten-day IVM training course conducted for participants from Ethiopia, Eritrea and Madagascar in July 2016. • *icipe's* ongoing participation 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	• *icipe* continued to consolidate its strategic positioning as the lead institution for research and capacity building in IVM in eastern and southern Africa. Priority continued to focus on Kenya, Ethiopia and the six southern African malaria elimination countries still using DDT for malaria vector control. • From September 2018 when GEF/UNEP/WHO-AFRO released IVM research funds amounting to US Dollars 838,311, *icipe's* IVM full technical team of 6 staff (2 senior scientists, 2 full-time post-doctoral fellows; 2 ARPPIS PhD students based in Zambia) has been responsible for providing technical guidance during the implementation of IVM demonstration/evaluation activities (house screening and winter-larviciding) in Botswana, Namibia, Swaziland, Zambia, Mozambique and Zimbabwe. • The national ethical clearance boards of Botswana, Swaziland, Namibia, Mozambique, Zambia and Zimbabwe approved AFRO-II project's in-country research protocols during the reporting period.	• The current AFRO-II project is significantly contributing to a strengthening of *icipe's* role as a key WHO partner in addressing vector-borne diseases in the African region.

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
The 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 symbionts with Malaria transmission-blocking properties Investigation into the potential of using microbial symbionts to block disease transmission.	• No. peer-reviewed publications. • Semi-field tests completed	• Discovery of transmission blocking symbiont, “Microsporidia MB” (1 preprint) • Utilization of transmission assays to investigate gene expression changes in *Plasmodium* (1 publication). • Preparation for semi-field tests underway.	• Transmission assays compromised by IRS spraying in region, suggesting better communication with local control programmes needed.
Objective: Contribute towards malaria elimination through the development of effective vector control strategies and public health initiatives by 2020				
At least two chemical-based technologies for surveillance and/or disruption of malaria transmission developed.	• Two large semi-field systems established at ITOC for investigating push-pull systems under near natural conditions by end 2016 • Oduor-baited traps used by scientists for mosquito surveillance in research programmes. • Use of odour-baited traps for mosquito surveillance by at least five locally active government and/or non-governmental agencies by 2020.	• At least two push-pull strategies evaluated for the control of host-seeking malaria vectors under semi-field conditions by end 2017. • At least one push-pull system investigated under field conditions by end of 2018. • Available trapping systems developed further to improve catching efficiency based on preliminary semi-field and field trails by end 2018. • Presence/use of attractant baited traps by researchers and national malaria control programmes. • Availability of a potent spatial mosquito repellent or repellent principal. • Number of publications in peer reviewed journals. • Project progress reports. • Theses. • Posters.	• All experimental tests and field trials completed. • One push component identified that provides 50% protection from bites in the indoor environment. • The tested pull technologies did not perform well and did not complement the impact of a spatial repellent. • manuscripts drafted for publication by end of 2020. • Spatial repellent available. • Odour-baited traps for monitoring available but due to their selectiveness for certain vectors only, not recommended for routine use of programs. Further work required.	• A final product for efficient and cost-effective push-pull interventions is not yet available. The performance of chemical based interventions appears inconsistent over test locations, there is need to standardize tests and also need to investigate the impact of climate variations. • The use of spatial repellents appears generally very promising for indoor protection but not for outdoors. Better pull strategies (traps, odours) are needed for combinations. • Semi-field-tests are not a very good estimator for field outcomes and rigorous field

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
				testing is required when evaluating a new product.
Studying the egg-laying behaviour of primary and secondary malaria vectors to develop novel attract and kill strategies (2017-2020)	• Protocols for rearing secondary vectors developed and colonies established at ITOC by 2019. • Oviposition bioassays implemented in cages and under semi-field conditions to screen for novel oviposition attractants from soil, swamp grasses and water-associated fungal cultures. • Different dispensing mechanisms for potential oviposition attractants tested in traps under semi-field and field conditions. • Field surveys implemented to investigate the correlation between swamp grasses and vector habitat colonization.	• Secondary vector colonies established. • Successful implementation of routine bioassays in cages and semi-field system with gravid female vectors. • Fungal cultures identified for natural vector habitats. • Swamp grass associated chemicals identified from water and headspace. • A number of new infusions and possibly chemicals tested for oviposition attractants. • Dispensers for attractants developed. • Risk factor analyses of field data implemented. • 1 PhD student trained/thesis produced. • No. of peer-reviewed publications.	• Most outcomes achieved. • Protocols for rearing secondary vectors developed and colonies established. • Oviposition bioassays implemented in cages and under semi-field conditions to screen for novel oviposition attractants from soil, swamp grasses and water-associated fungal cultures. • Field surveys implemented to investigate the correlation between swamp grasses and vector habitat colonization. • Chemical analysis of headspace from attractive plants implemented and approximately 12 putative semiochemicals identified. • 2 manuscripts drafted for submission between May and August 2020. • 1 PhD student trained and 3 thesis chapters completed. • 1 MSc student trained.	• Oviposition behaviour of Anopheles mosquitoes very complex. Plant cues play an important role in attraction in various behaviours of mosquitoes and key will be to understand how they interact with other cues in the environment to use them for trapping.
A potent synthetic lure derived from screening three mosquito-preferred plants developed by 2020	• 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	• Stereoisomers of plant-based attractant (linalool oxide) synthesized • 1 MSc thesis submitted (Julia W Jacob)	
Establishment of an arthropod containment level 2 facility for research and training purposes at *icipe*-Thomas Odhiambo Campus.	• Facility completed and accredited by the National Biosafety Authority (NBA) end of 2017.	• Accreditation certificate. • Number of staff trained in Biosafety.	• Facility commissioned by the NBA. • Facility fully equipped and operational.	

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
Conduct studies on the genetic structure of the key malaria vector, *Anopheles funestus* by 2018.	• Knowledge on the genetic relatedness of different populations of *An. funestus* by 2018. • Knowledge on the distribution of sibling species in the *An. funestus* group and role in malaria transmission by 2018.	• Number of peer-reviewed publications.	• Uncovered a potential novel malaria vector in Kenya within the *An. funestus* group. • Genetic subdivision in a key malaria vector, *An. funestus* s.s. with variation in *Plasmodium* infection rates demonstrated. • Two papers published: Ogola et al 2019, Parasit Vectors 12:15; Ogola et al 2019, Parasit Vectors 12:80.	
Overall Objective: Epidemiologic assessment of risk of yellow fever (YF) and dengue (DEN) transmission and outbreaks in Kenya				
Objective: **To determine existence and locality of YF, DEN transmission foci in Northern Kenya at border with endemic countries**				
Existence and locality of YF, DEN transmission foci in Northern Kenya at border with endemic countries determined.	• Research team confirms presence/absence transmission between primate and human populations.	• Community engagement. • Publications. • Donor and other reports. • Stakeholder information sharing meetings	• Seroprevalence data of YF/DEN and other flaviviruses in humans from two ecologies, West Pokot and Turkana counties documented. • 1 article published: Chepkorir et al 2019: Virology Journal 16(1):65; DOI:10.1186/s12985-019-1176-y • New sites and populations in Rift Valley and Coastal Kenya identified • Human population to be sampled blood followed by analysis.	
Objective. Assess vector species presence and their YF/DEN vector potential in the selected areas				
Vector species presence and their YF/DEN vector potential in the selected areas assessed.	• Research team detects and maps known and/or other potential YF and dengue vectors.	• Publications. • Donor and other reports. • Stakeholder information sharing meetings	• Data on vector presence and bionomics underway in the 2 new ecological sites targeting known YF/Den vectors: *Aedes aegypti*, *Aedes africanus*, *Aedes simpsoni* s.l., *Aedes metallicus* and *Aedes vittatus* • Data on molecular speciation and genetics of identified vectors ongoing • Students enrolled in study (2 PhD, 3 MSc)	
Objective. To assess the potential for urban *Aedes* vectors to sustain an outbreak in major urban centers in Kenya				
The potential for urban *Aedes* vectors to sustain an outbreak in major urban centres in Kenya assessed.	• The researchers identify the competent and refractory vector populations for	• Publications. • Donor reports. Stakeholder information sharing meetings	• 1 Thesis submitted and defended (Sheila Agha) • 1 PhD student graduated (Dr. Sheila Agha) • 1 paper published: Agha et al 2019: PLoS NTD 13(8):e0007686; DOI:10.1371/journal.pntd.0007686	

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
	transmission of YF and DEN.			
Objective. To develop trapping tools for conducting vector surveillance to improve surveillance of YF and dengue				
Trapping tools for conducting vector surveillance to improve surveillance of YF and dengue developed.	• The team identifies suitable odours and tools for attracting and sampling YF and DEN vector populations.	• Publications. • Donor and other reports. • Stakeholder information sharing meetings.	• Olfactory interactions between *Aedes* mosquitoes and human and non-human primate hosts in the domestic and sylvatic environment elucidated. • Human and primate-derived attractants identified and evaluated. • 1 article published: Tchouassi et al 2019, Proceedings of the Royal Society B. 286: 20192136. DOI:10.1098/rspb.2019.2136	
Overall Objective. Understanding the risks and benefits of newly developed irrigation schemes in western Kenya in the context of malaria elimination				
Objective: How does introducing gravity-fed irrigated agriculture impact land-use, aquatic habitat distribution and vector production?				
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	• Good progress towards outcomes. • The longitudinal risk factor surveys are ongoing and data entry and cleaning ongoing. • All areas comprehensively mapped. • Regular stakeholder meetings implemented.	• Irrigation projects did not progress in the stipulated timeline indicated at the start of the project. This has led to some delays, but quick adjustments of study sites has ensured that original questions will be answered at end. • Since this is a longitudinal study, comprehensive data analysis and publication can only be done at end of project period.
Objective: Does irrigation lead to an increase in adult malaria and non-malaria vectors, changes in species composition, seasonality, biting patterns or sporozoite infections?				
1Association 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.	Good progress towards outcomes. The longitudinal malaria and vector surveys are ongoing and data entry and cleaning ongoing. Sub-sample analysis implemented. Information shared during conferences and meetings.	See above

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
		• Publications and conference presentations. • Stakeholder information sharing meetings. Progress reports		
Objective:. Can irrigated agriculture be associated with changes in socio-economic and nutritional status, malaria prevention measures and/or behaviours and prevalence in the population?				
1. 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	• Longitudinal data collection ongoing and on track. • Focus group discussions and in-depth household surveys implemented. • Data cleaning ongoing for preparation of analysis.	
Objective: What are the important geo-spatial variables responsible for malaria propagation on a farm- and landscape-scale?				
1. Geospatial variables for malaria propagation on farm and landscape identified.	• Improved awareness of the important geo-spatial variables responsible for malaria propagation on a farm- and landscape-scale by all project stakeholders by end 2020.	• The spatiotemporal dynamics in terms of expansion of irrigated lands, changes and current status of cropping patterns (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	• Longitudinal data collection ongoing and on track. • Satellite images received and reviewed.	
Overall Objective: Understanding freshwater pollution and the links to the distribution of Schistosoma host snails in Western Kenya				

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
Objective: Does the abundance of host snails for human pathogenic trematodes increase with pesticide pollution, and is this increase associated with a decrease of antagonistic macroinvertebrate species? *Does the portion of infected host snails and the number of Schistosoma cercariae produced by infected snails change with pesticide pollution? Can the pesticide pollution in tropical freshwater bodies after runoff be predicted from the community composition of sensitive and insensitive macroinvertebrate taxa?*				
1. Risk factor analyses implemented. 2. Pollution associated with abundance of snails, antagonistic invertebrates, and ceracaria infection.	• Pesticides bioindicator index developed for the effect of pesticide pollution on macroinvertebrates to tropical freshwater habitats by 2020.	• Filed sites identified • Two field campaigns successfully completed, • Dataset compiled for analysis. • Publications. • Donor and other reports. • Thesis chapter.	• Completed: • Pesticides bioindicator index developed for the effect of pesticide pollution on macroinvertebrates to tropical freshwater habitat. • 2 manuscripts published: https://doi.org/10.1016/j.scitotenv.2020.136748 https://doi.org/10.1038/s41598-020-60654-7 • Donor report submitted, 2 thesis chapters written.	• Pollution decreases biodiversity and increases host snails increasing risk of schistosomiasis
Objective: What is the acute pesticide sensitivity of host snails compared to relevant antagonistic species?				
1. Pesticide sensitivity established in comparison to antagonistic species.	• Tools available to predict impact of pesticide pollution on snail distribution by 2020.	• Toxicity tests designed and successfully implemented. • Publications. • Donor and other reports. • Thesis chapter	• Near Complete: • Tools available to predict pesticide pollution, 1 manuscript in advanced draft for submission in 2020. • Donor report submitted, 1 thesis chapter written.	• Challenges in implementing laboratory experiments with invertebrates and how to overcome.
Objective: Does the composition of pathogenic and non-pathogenic trematode species differ in host snails from polluted and non-polluted sites?				
1. Composition of pathogenic and non-pathogenic trematode species from host snails identified.	• Risk of schistosomiasis based on habitat pollution assessed for predicting disease risk by 2020.	• Laboratory techniques established, • Successful analyses of data • Publications. • Donor and other reports. • Stakeholder information sharing meetings. • Thesis chapter.	• Lab techniques established, • Experiments and analysis ongoing. • Completion expected end of 2020.	n/a
Objective: Experiments to investigate how pulse exposure to pesticides affects the competitive balance and the predator-prey relationship of the most common host snails and their natural antagonists; how does pulse exposure to pesticides affects the production of cercariae in the host snails, and how pesticide exposure affects the survival of cercariae in the absence and presence of predators.				
1. Experimental assessment of impact of pollution on predator-prey relationships, snail vector competence	• Risk of schistosomiasis based on habitat pollution assessed for predicting disease risk by 2020.	• Macrocosm experiments established and completed, • Database established, • Publications. • Donor and other reports.	• Macrocosm experiments concluded. Data analysed. • Publication drafted in conjunction with objective 5.2.	n/a

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
and parasite survival.		• Stakeholder information sharing meetings. • Thesis chapter.		
Overall Objective: Investigating the disease ecology of tungiasis (sand flea disease) for the development of treatment and prevention strategies **Objective: Analyzing school- and household-based risk factors associated with disease outcome**				
Risk factors associated with disease identified.	• Improved awareness of the association between certain environmental, socio-economic and behavioural risk factors and disease by all project stakeholders (scientists, Ministry of Health, communities) by end 2018. • Recommendations for prevention articulated by end 2018.	• Ethical approval for study. • Field surveys completed. • Dataset compiled for analysis. • Statistical analysis. • Publications. • Donor and other reports. • Proposals for prevention trials developed.	• Study completed. Outcome achieved. • Manuscript published: https://doi:10.1371/journal.pntd.0007326 • New projects funded. • Working Group on Ectoparasites at the MoH NTD Unit established.	• Simple interventions can target the risk groups and would be able to prevent over half the cases.
Objective: Testing of herbal remedy used by communities based on neem oil for tungiasis treatment in a clinical trial (phase II)				
The impact of neem oil treatment on tungiasis infestation and inflammation established. .	• Novel treatment recommendations that can be incorporated in the Kenya National Guideline for Tungiasis Control by end 2018.	• Ethical approval for study from KEMRI granted. • Approval for the study granted by the Expert Committee for Clinical Trials of the Pharmacy and Poisons Board. • Independent Trial monitor contracted. • Trial documentation, forms, SOPs, monitoring plan, etc compiled as per national guidelines. • Project staff training completed. • Field survey completed. • Dataset compiled for analysis. • Statistical analysis. • Report to Expert Committee for Clinical Trials. • Donor eport. • Publication.	• All indicators and study completed. Outcome achieved. • Manuscript published: https://doi:10.1371/journal.pntd.0007822 • New projects funded. • Working Group on Ectoparasites at the MoH NTD Unit established. Several counties are in the process to recommend the oil as first-line treatment, Kilifi County already uses it large scale.	• Neem oil and coconut oil is a very promising alternative for treatment of tungiasis that is locally available and can be used on household and school level. • The challenge is now to increase production under GLP and register as product.

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
		• Proposals for phase III study		
Objective:. Developing tungiasis prevention tools				
Impact of novel prevention tools known.	• Recommendations for prevention made to Minsitry of Health for incorporation in the Kenya National Guideline for Tungiasis Control by end 2020.	• 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.	• Two proposals have been approved for funding, one is already ongoing since February 2019, the second has been approved but no started yet. • Both projects to investigate the impact on improving house floors on tungiasis. • Ethical approval granted for the first project. • Randomized trial intervention implemented, follow up surveys ongoing. • Intermittent data analysis ongoing.	• There is a great need to develop projects investigating the improvement of homes (healthy homes) on health outcomes in children and adults.
Overall Objective: Surveillance of arbovirus and mosquito vector diversities and their blood-meal host populations.				
Development and use of HRM-based blood-meal host identification.	• Unique arbovirus-mosquito-host relationships identified	• 2 peer reviewed publications • Additional grant funding obtained based on this work. • 3 students trained	• Data analysis and study completed on samples collected in Kwale and the Maasai Mara regions of Kenya. • One publication: Musa AA, Mutiri MW, Musyoki AM, Ouso DO, Oundo JW, Makhulu EE, Wambua L, Villinger J & Jeneby MM. Arboviruses and blood-meal sources in zoophilic mosquitoes at human-wildlife interfaces in Kenya. Vector Borne Zoon. Dis. 2020 Mar 5, in press [Online ahead of print] doi: 10.1089/vbz.2019.2563. PMID: 32155389 • Students trained Ali Musa (MSc), Tatenda Chiuya (PhD), Edwin Ogola (PhD)	• Obtained evidence of sylvatic transmission of dengue virus in the Maasai Mara National Reserve. • Identification of possible new vectors of dengue virus (*Aedes tarsalis* & *Aedes tricholabis*)
Overall Objective: New arbovirus transmission blocking strategies				
Characterization of endemic insect-specific flaviviruses (ISFVs) in their capacity to affect vector competence of mosquitoes to arboviruses.	• The potential utility of ISFV's for blocking arbovirus transmission identified. • Strategy for arbovirus transmission pursued	• Funding • Publications • Experimental data collection completed	• Lab work commenced to experimentally assess the effect of ISFVs on mosquito vector competence. • Two new grants: • ANTI-Vec (GCRF) funding (£100k) for project: "Roles of insect-specific flaviviruses and immune priming in arbovirus transmission blocking in mosquitoes." (Apr 2019-Jul 2020)	• Potential procurement delays must be better considered in planning.

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
			• Wellcome Trust MSc fellowship (US&155k) for Joseph Njuguna on project: "Investigations into how Anopheles-specific flaviviruses affect arbovirus and Plasmodium transmission." (Aug 2020 – Feb 2023). • One Publication: Patterson EI, Villinger J, Muthoni JN, Dobel-Ober L & Hughes GL. Exploiting insect-specific viruses as a novel strategy to control vector-borne disease. Current Opinion in Insect Science 2020;39:50-56.	
Overall Objective: Understanding the ecology of sandflies and leishmaniasis transmission dynamics in Kenya and development of control strategies **Objective: Mapping 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.	• Established extent of plant feeding and specific plants fed upon by sand flies of both *Sergentomyia* species and those belonging to *Phlebotomus* genus including the leishmaniasis vectors *P. duboscqi* and *P. martini*. • Elucidated the sand fly abundance and diversity patterns in selected habitat types and the chemical basis for such preferences. • **Two Publications** • 1. Describing four potential vectors of Leishmania parasites, and two sand fly species-parasite associations: Owino BO, Matoke-Muhia D, Alraey Y, Mwangi JM, Ingonga JM, Ngumbi PM, et al. (2019) Association of *Phlebotomus guggisbergi* with *L. major* and *L. tropica* in a complex transmission setting for cutaneous leishmaniasis in Gilgil, Nakuru county, Kenya. PLoS Negl Trop Dis 13(10): e0007712. https://doi.org/10.1371/journal.pntd.0007712 • 2. Conference presentation documenting the occuence of the sand-fly species and leishmania parasite: Matoke-Muhia et al. 2019. *L. major* and *L. tropica* in a complex transmission setting for cutaneous leishmaniasis in Kenya. ICOR-NTD Conference Radisson Blu Nairobi on 4th - 6th December 2019	• New sand fly vector – Leishmania parasite associations described. Need for further investigations. • Distribution of sandflies non-random, even on a fairly small geographic scales. Investigating this can provide new knowledge that can improve sand fly control.

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
			• 2 Publications describing the magnitude and pattern of the outbreak of VL in Marsabit County. Dulacha et al. 2019. Epidemiological characteristics and factors associated withVisceral Leishmaniasis in Marsabit County, Northern Kenya. J Interv Epidemiol Public Health. 2019 Mar; 2(1)	
Understanding dynamics of Visceral and Cutaneous Leishmaniasis transmission in Baringo, Nyandarua and Nakuru Counties in Kenya	Establish the behavioral, ecological and socio-economic characteristics that contribute to VL occurrence and transmission	• Publication • Project reports • Conference presentations.	• One conference presentation highlighting the behavioral, ecological and socio-economic characteristics of household members in VL endemic areas. • Nyakundi H et al. 2019. Behavioral, ecological and socio-demographic correlates for Visceral Leishmaniasis transmission in Baringo, Kenya at 68th ASTMH 20th – 24th November Maryland, USA	• KAP studies are important determinants of community participation in the control of Kala-azar. • An integrated control and prevention strategy using household dynamics will have the greatest impact.
Leishmaniasis parasite identification	Vectors screened of leishmaniasis parasite species	• Publication • Project reports • Conference presentations.	• One publication describing two species of Leishmania parasites: *L.* major and *L. tropica* and their association with *Phlebotomus guggisbergi.* • Owino BO et al (2019) Association of *Phlebotomus guggisbergi* with *L. major* and *L. tropica* in a complex transmission setting for cutaneous leishmaniasis in Gilgil, Nakuru county, Kenya. PLoS Negl Trop Dis 13(10): e0007712. https://doi.org/10.1371/journal.pntd.0007712	
Objective: 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	• Evaluation of responses of *Phlebotomus dubosci* to visual cues undertaken. • A prototype trap design developed to facilitate testing.	
Vector species for Cutaneous leishmaniasis and parasite transmission	• Identification and mapping of cutaneous leishmaniasis vectors	• Publications. • 1 MSc • Stakeholder information sharing meetings.		

Outputs	Outcomes	Performance Indicator	2019 Progress made in Achieving the Outcomes	2019 Lessons Learned
in Gilgil, Nakuru County identification	• Ecological factors mapping Cutaneous Leishmania reservoir identification			
Correlation of exposure to sand fly bites and the CL outcome and the risk factors associated with disease exposure in Gilgil.		• Publication • Project reports • Conference presentations.		
Objective: Identifying sand-fly endosymbionts and their potential effect on leishmaniasis transmission.				
Identify the diversity of *Wolbachia*, *Rickettsia*, *Spiroplasma*, *Arsenophonus*, *Cardinium*, and microsporidia symbionts in Kenyan sand-fly species.	Identification and mapping of endosymbionts.	• Publication • Stakeholder information sharing meetings.	• Several sand-fly endosymbionts have been identified in colony specimens, most importantly *Serratia*	
Experimental correlation of symbiont infection with infectivity to *Leishmania*.	• Establishment of sand-fly colonies • Identification of transmission blocking potential of key endosymbionts	• Publication	• Made some advances to establishment of sand-fly colonies.	

7.5 Environmental Health Theme: Results Based Management (RBM) Rolling Framework Report

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
Objective 1: Survey, inventory, and description of new species of East African insects published and data made internet-accessible by 2020.				
1.1 At least 35 taxonomists agree to study and publish results of examination of insects collected in Burundi and Kenya, by 2020.	• Taxonomists agree to study East African specimens.	• Number of taxonomists agreeing to participate.	• Number of collaborating taxonomists has now increased from 32 to 46	• Taxonomists continue to show interest in working on the East African insect fauna. Underestimate of number of taxonomists. Change to 50 in RBM.
1.2 At least 35 taxonomists agree to study and publish results of examination of insects collected in Burundi and Kenya, by 2020.	• Taxonomists study and publish on East African insect taxa.	• Number of manuscripts published on generic revisions, species descriptions, and regional checklists.	• Five papers were published during 2019. The number of peer-reviewed publications since 2014 now equals 23.	• The previous number of published peer-reviewed papers was miscalculated and overestimated. Change to 28 in the RBM.
1.3. At least 15,000 specimens databased by 2020, 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.	• 26,197 specimens have received unique ICIPE number labels. Of these, complete collection data of 17,761 specimens have been entered in the database.	• Number of specimens databased is underestimated, change to 20,000 in RBM. Also, lack of visits to ICIPE collection by expert identifiers has limited the number of specimens with complete identifications.
1.4. At least 10 taxonomists or biogeographers cite (via GBIF) *icipe* collection database in papers or reports by 2020.	• Taxonomists and biogeographers access data base and use data in independent reports or papers.	• Number of reports or published papers.		• References to ICIPE unique database specimen numbers began being added to new species descriptions in 2019. Several authors have cited ICIPE's collection in their papers, but not the ICIPE database specifically.
1.5 At least 200 new species discovered in East Africa and described in peer-reviewed journals by 2020.	• Knowledge of East African insect diversity is increased and National Museums of Kenya type collection increased appreciably.	• Number of published papers.	• As of end 2019, 172 new species have been described and published in peer-reviewed journals. In addition, 21 more are in manuscript.	• On track to reach our goal of 200 new species described. However, the closure of museums around the world due to corona virus may impact taxonomists, as may their work loads.

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
Objective 2: Information on important pollinating Diptera (true flies) collected and made available on the internet.				
2.1. ICIPE's collection of fly pollinators databased and made available to the international community on GBIF by 2019.	• Data on Diptera important in plant pollination services made available to conservation biologists, taxonomists and interested parties.	• Number of visits to GBIF, including number of downloads of data.	• The total number of ICIPE's databased specimens of the three important fly pollinator families remains the same as last reported; 2122; flower flies (1462), Pangoninae horseflies (124) and Bee flies (536).	• A number of recently collected Pangoninae:Tabanidae, Bombyliidae, and Syrphidae specimens have not yet been entered in the database. • Database of Syrphidae collection held at ICIPE has been sent to GBIF for data cleaning. Expected that database will be uploaded to GBIF website in early-mid 2020. Change in RBM from 2019-2020.
2.2 Three field visits per year through end of 2019 made to Nairobi forests to collect fly pollinators.	• Information on fly pollinators is increased, underscoring importance of the insect order in providing pollination services.	• Database of fly pollinators increases during period indicated.	•	• Recently collected flies have yet to be databased. Database management took back seat to preparation of manuscripts and intensive collecting in western and eastern Kenya, creating a substantial backlog of work.
2.3 One two-week training of African nationals in fly identification and their importance in plant pollination to be held at ICIPE in 2019, in connection with JRS Biodiversity Foundation grant on fly pollinators	• Information on fly pollinators is disseminated throughout sub-Saharan Africa by trainees	• Post-training reports by trained African nationals. Aspects of fly pollination included in projects organized by trainees.	• Two-week training was held in 2019 at Sokoine University, Morogoro, TZ.	• Reports from trainees have not yet appeared on the project website (pindip.org/Syrphidae) maintained by the Royal Museum For Central Africa, the project lead institute. It is probably too early for reports to have been produced since most trainees are students and have not yet initiated or joined projects related to fly pollination.

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
Objective 3: Taxonomic information on African insects including major African pests and vectors used by scientists, students and public by 2020.				
3.1: 10,000 DNA barcodes generated for the iBOL database.	• Scientists use the DNA-barcode library for the African pest and vector insects to identify pest species with DNA techniques. • DNA barcoding becomes a routine part of the taxonomic enterprise. • A taxonomic evaluation of poorly understood taxa, like stingless bees and African silkmoth species.	• Number of barcodes generated.	• As of end 2018, 33,3198 specimens were run, of which barcodes were generated for 17460	• No barcoding was conducted during 2019 due to financial constraints (costs for barcode generation)
3.2 One training per year for 10–15 students and staff.	• Students and staff know and apply modern taxonomic techniques, including morphological identification, preparation and DNA techniques to identify insects.	• Number of students and staff members trained.	• PhD candidates received training in December 2019	
3.3. At least four donor-funded projects with relevant taxonomic perspective request and receive taxonomic and/or photographic support from the Biosystematics Support Unit by 2020.	• Scientists incorporate taxonomic information into planning and carrying out of projects.	• Number of projects funded that incorporate taxonomic data.	• Projects from all four of ICIPE's thematic units requested and received taxonomic and photographic services from the Biosystematics Unit. Twenty-four (24) separate commissions were undertaken and included, mainly, work on Avocado pollinators, Tsetse, ticks, *Spodoptera frugiperda* (Fall Army worm), Tuta absoluta (tomato leafminer), *Helicoverpa armigera*, (Old World (African) bollworm), Hippobosca (biting flies), Edible insects among several families including Saturniidae, Formicidae, Tettigoniidae and Acrididae.	• Demand for BSU services remained relatively robust across ICIPE thematic units and projects, despite the fact that BSU services are now monetized.
3.4 Aquatic insects of streams in East Usambara area of Tanzania are identified and local groups are trained in their identification by 2018.	• Local groups of farmers are capable of identifying these insects, and can monitor the quality of streams.	• Number of community members trained.	• Total number of community members trained was 9723. Expert TOTs (trainers of trainers) were 8 and 18 teachers participated.	• This successful project was completed in 2018. Remove from RBM?
Objective 4: At least 6 new eco-friendly nature-based products for pest and vector control adopted for improvement of livelihoods of rural and wider community members by the year 2020.				

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
4.1.1. At least four new potential products for mosquito control identified from plants based on efficacy, safety and ease of application. 4.1.2 At least two plant-derived products for mosquito control formulated and packaged. 4.1.3. Community-based cultivation of selected insecticidal plants initiated. 4.1.4. Community-based production and use of plant-derived products for mosquito control initiated in at least one project site. 4.1.5. At least two PhD and two MSc students trained. 4.1.6. At least three papers prepared and submitted to international journals.	• Two plant-derived insecticidal products adopted for use in mosquito control by a local community by 2020. • Three papers or patents on potential mosquito control products published by 2020.	• Number of products produced and used. • Number of community members using the mosquito control products. • Number of reports and publications. • Number of students trained.	**Products** • One repellent product formulated and Screened for efficacy as repellent against malaria vectors. The KARIRE Lotion formulation provided an average of 69.5±15.5% of repellence • Nepetalactone was > 90 % in both wet and dry hydro-distilled oils of *Nepeta cataria* used for formulation of Karire mosquito repellent lotion • Community-based cultivation of 5 insecticidal plants ongoing in Ethiopia, Kenya, Burundi and Tanzania. • 2 Ph.D. students trained. **2 Reports submitted** • Up-scaling sustainable commercial production of medicinal plants by a community-based conservation groups at Kakamega forest in Kenya • Sustainability of medicinal plants-based enterprises and biomonitoring of environmental health for targeted communities in Kenya and Tanzania **Registration**: • Uzimax EC a mosquito larvicide granted a registration certificate as a Pest control product by Pest Control Products Board of Kenya. **Patent:** • Lwande W., Ochola J. B., Marubu R. M., Moreka L., Nduguli F.W. and Ligare J., Composition and Method for Controlling Larvae. Patent No: KE/UM/2015/00569. **Manuscripts**: • Paul Nyang'au, Beatrice Muriithi, Rose Marubu, John Bwire, Nixon Onyimbo & Janet Irungu (2019): Effect of participation in commercial production of medicinal	• Policies that address the economic and legal barriers to product commercialization, as well as financial incentives, should be prioritized • Bringing markets closer to the farms is likely to increase participation among Medicinal Plant producers • There is need of upscaling the commercial production of Medicinal plants to other areas of similar agro-ecological and socio-economic contexts, especially among forest adjacent communities to improve incomes and conserve the forest

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
			plants through community-based conservation groups on farm income at Kakamega forest, Kenya, Journal of Sustainable Forestry, DOI: 10.1080/10549811.2019.1689145 • John Bwire Ochola, Clifford Maina Mutero, Rose Muthoni Marubu, Lamberts Moreka, Barbra Frei Haller, Ahmed Hassanali, Wilber Lwande. Mosquito larvicidal activity of *O. kilimandscharicum* essential oil and its water-miscible formulation under laboratory and semi-field conditions. Scientific Reports (in press).	
4.2.1 Two plants with bioactivity against honeybee pests/diseases identified. 4.2.2. One plant-derived product formulated and evaluated for control of a honeybee pest/disease. 4.2.3. The bee pest/disease control product submitted for registration with relevant bodies. 4.2.4. Protocols for production of the bee pest/disease control product established.	• One plant-derived product for honeybee pests/diseases control adopted for production and in use by 2020. • Two publications/utility model/patent on potential honeybee pest control products published by 2020.	• Number of products produced and used. • Number of reports and publications.	• Apicure®, an essential oil-based biopesticide was evaluated for its role of olfaction in small hive beetle(SHB), *Aethina tumida* whose response showed that it has potential for the management of honeybee pests and diseases. • EAD analysis isolated 11 compounds from Apicure® volatiles that elicited antennal response with the Small hive beetle (SHB), of these, linalool, camphor, geraniol and α-terpineol were confirmed to be strongly repellent, while limonene was attractive to SHB in dual-choice olfactometer assays. As such the results demonstrated that the major components in Apicure® are mainly repellents thus prospective in disrupting the host recognition by the SHB. The product therefore can be up scaled for the management of SHB. **Publication** • Komen E, Murungi L K and Irungu J (2019).Behavioural response of the small hive beetle, *Aethina tumida* (Coleoptera: Nitidulidae) to volatiles of Apicure®, a	

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
			plant-based extract [version 1; peer review: AAS Open Research 2019,2:9 (https://doi.org/10.12688/aasopenres.12946) **Patent:** • World Intellectual property Organisation (WIPO): PCT/IB2016/055576.	
Objective 6: Increasing honey and silk production by 20% in selected African farming communities by 2020				
6.1 Potential and healthy silk and bee races identified for enterprise	• Development of strains and identification of hybrids with productive merit	• Morphometrics and DNA fingerprinting results.	• Comparison of phytochemicals (Phenols and flavonoids) *in Samia cynthia ricini* (Eri silk) and *Bombyx mori* (mulberry silk) was completed for first generation. • Samples for wild silkmoths collected in Mwingi county, Arabuko Sokoke forest and Makueni county for DNA analysis in collaboration with SATREP project (Science & Technology Research and Partnership for sustainable Development. • Two (2) races of Bombyx mori introduced from Japan through SATREPS project for performance evaluation.	• Unpredictable change of seasons affects samples collection.
6.2 Healthy silk and bee races are distributed to 1,000 trainers for the farmer groups.	• •60% of the farmers use improved bee and silk races	• •Number of farmers using improved races.	• 600 cocoons supplied to YESH program with a productive capacity of 120,000 eggs.	• The number of farmers is increasing, the eggs production should also be increased
6.3 At least 5 PhD and 10 MSc students trained.			• Four MSc students (three in Ethiopia and one in China) supported by the YESH project have completed their thesis research.	
6.4 At least 50 peer reviewed papers and five books/proceedings published in international journals.			• Two papers published in international proceedings (Ngoka) • Two manuscripts published (XYESH Ethiopia)	
6.5 Training material developed, and training sessions held for 2,000 trainers.	• Knowledge of sericulture and apiculture is applied by at least 750 farmer groups (each 50 to 100).	• Number of farmers trained. • Number of certificates (exam). • Number of farmers applying their new knowledge.	• 12 Trainers Trained through YESH/MOYESH program • 2 Technical staff members acquired international certificate on sericulture	• Exchange programs are important

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
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.	• Altogether the project so far established 1,049 new beekeeping (75%) and sericulture (25%) enterprises and more than met its target of recruiting and engaging 10,000 youth in beekeeping and 2,500 youth in sericulture.	• This approach of generating gainful jobs for unemployed youth in commercial insects was adopted in the MOYESH program to generate 100,000 new direct jobs in five years from October 2019.
6.7 16 to 20 marketplaces (honey and silk harvesting, processing and selling units) established.	• 10% increase in honey and silk quantity by 2020	• DC registry. • Production records.	• During 2019 the 4 honey and beeswax marketplaces established earlier by the YESH project have been fully operational; 9 new ones were also established, 8 by the EIF Honey Trade project and another one by the BV Pilot beekeeping project. At sericulture sites 4 marketplaces were established.	• Properly setup product aggregation and processing marketplaces enhanced access to more attractive formal markets. They also facilitate standardization, quality assurance and traceability of products. Building up on these learnings, the MOYESH program will establish at least 40 such marketplaces in Ethiopia.
6.8 Modern beehives supplied to farmers and rearing houses (silk moth) established.	• 500 beehives supplied to farmers by 2020.	• •Project records.	• Eight (8) new rearing house established by farmers and private sector through onsite training in Kenya. • During 2019, the YESH project distributed 3,685 Langstroth frame hives and necessary hive tools. Also, over 7,530 bamboo and wooden silkworm rearing trays and mountages were distributed to project beneficiary youth in sericulture sites.	• Encourage private sector collaboration • Manufacture of locally produced beekeeping and sericulture starter kit items generates lots of direct and indirect jobs to unemployed youth. The MOYESH program set out to establish hundreds of such input supplier youth enterprises across the country by providing skills. training, market access and credit facilities.
6.9. Internal control system (ICS) training for 3,000 trainers conducted.	• Percentage of communities producing honey and silk to European Union (EU)			

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
Objective 7: Integrative Pollinator-Plant Interaction Assessment of Ecosystem Service Diversity in Sub-Saharan Africa (JRS Biodiversity Foundation Project) by the year 2020				
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.		• Private partner for platform development stepped out of project, new partnership established
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).	• 17,000 records collected.	
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.		• Common species to be identified.
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.		• Networks to be established from field-based collections.
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.		• To be provided from field-collected samples.
7.6.Capacity building of stakeholders in database usage.	• Increased uptake of database usage by other stakeholders.	• Data records on interactions deployed.		• Dependent on database development.
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.		• To be initiated when database is developed.
Objective 8: Promote knowledge and technology-based entrepreneurship through training in beekeeping and silk farming for youth employment in Ethiopia (YESH Project) by 2020				
8.1 In-depth value chain analysis of beekeeping and silk production in the targeted project zones undertaken.	• At least two value chain analysis reports produced and shared with donors and partners by end of 2016. • One scientific publication by end of 2019. • Gender mainstreaming strategy designed by 2017.	• Map the major processes that the raw materials produced (honey, beeswax, cocoons) go through before reaching the final consumption by early 2017. • Identify and map the main actors involved in the processes by end of 2017. • Identify the flows of products as well as information flow and knowledge in the value chain by 2017	• The two value chain analysis reports produced – one on apiculture and another on sericulture – were finalised, validated and submitted to the Mastercard Foundation. Both reports mapped main actors and the flows of products in the value chain. • Baseline production levels were quantified as part of the M&E framework. Bottlenecks in the value chains were identified. • Two project progress monitoring reports were produced.	• Both value chains are highly dynamic, and the reports will need to be updated after a few years.

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
		• Quantify the volume of different products in the value chain by early 2018. • Identify relationships and linkages between value chain actors by 2018. • Identify the bottlenecks within the supply chain and where possible identify/refine interventions by 2018.		
8.2 The knowledge, capacity and technology-based entrepreneurship within the currently unemployed youth population increased.	• At least 8,750 youth capable to generate or improve income from beekeeping and silk farming or other businesses from the acquired skills by 2020. • At least 12,500 youth trained in beekeeping and silk farming enterprise development during the period 2016–2020 • Gender mainstreaming strategy designed by 2018. • Support at least one egg production facility by 2018. • Develop at least two training manuals by end of 2016.	• Identify, profile and select youth to form groups with a good balance in gender by 2019. • Establish training and demonstration centres for beekeeping and silk farming activities by 2019. • Build capacity through training (technical, business and life-skills), provision of starter kits and material support to improve beekeeping and silkworm rearing technologies and post-harvest handling for high quality production and income by 2020. • Increase participatory tree plantation to improve bee biodiversity, provide silkworm feed and enrich the ecosystem by 2020. • Provide technical support using existing egg production facility (grainage) within the Region by 2020.	• By end of 2019, a total of 13,424 (38% females) YESH project beneficiary youth were recruited and engaged. 92% of these were trained in entrepreneurship and technical skills development; 9,912 (32% females) of these started business in apiculture and 2,431 (65% females) in sericulture. • Gender mainstreaming strategy document finalized, reviewed and finalized. • One private silkworm grainage identified in 2016 and has been supported through to end of 2018 to expand its seed production and maintenance activities. The facility continued to provide practical training for 167 (17% females) youth silkworm farmers and 20 local sericulture extension staff. • Nursery site development activities on a variety of multipurpose bee forages have been distributed to all sites; sericulture sites also received castor seed as well as seeds of vegetables for complementary income generating activities.	• Some youth enterprises are engaged in other income generating side businesses taking advantage of the entrepreneurship training they have received from the project. Some youth enterprises have disbanded due to poor group motivation and lack of cohesion. • The lessons learned in the YESH project justified development of the MOYESH program to scale up the progress made across four Regional States for five years from end of 2019 and generate a total of 100,000 direct jobs in the two value chains.
8.3 The development of youth-led and owned, silk farming and beekeeping enterprises through business development/incubation supported.	• At least 70% of youth using skills acquired from the entrepreneurship training able to build or increase assets during the period 2016–2020. • At least 50% of youth engaged in beekeeping and	• Provide training in assessing market information, improving marketing skills and analyzing market linkages in the value chain in the period 2016–2020. • Educate the young entrepreneurs in financial management and mediate in acquiring access to appropriate	• By end of 2019 a total of 1049 youth-led and owned enterprises were established from the Year 1 to 4 cohorts of the YESH project beneficiaries, with 884 in apiculture sites and 165 in sericulture sites. • Each of the enterprises have opened savings bank accounts with local microfinance institutions in preparation to gain access to their credit services but delivery of credit service has	• Securing suitable and accessible micro-finance services to support development of the value chains has been more challenging than expected. • The pilot collaboration with a small private microfinance institution

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
	silk farming able to access financial service by 2020.	financial services and products by 2020. • Provide a pro-active business development service by mentoring and coaching by seasoned entrepreneurs and advisers as well as helping to navigate regulatory requirements, standards and compliance by 2020. • Support youth to participate in agribusiness entrepreneur networks, competitions and fairs to promote products, forge partnerships and learn about developments in the industry by 2020. • Assist the young entrepreneurs to gain access to technology and information by providing technical training by 2020.	been very low; the project then piloted a credit service with a private microfinance institution, which in one opened 4 new branch offices and started delivering savings and credit service to youth enterprises. • Arrangements were made with local key institutions for availing business development services and mentoring • A total of 319 experienced local extension staff attended ToT workshops, and 89 of these also attended one week of intensive training in adult learning skills development. • A total of 27 model female youth beekeepers attended practical peer-to-peer on-site training in colony inspection and multiplication. Likewise, a total of 167 model youth silkworm farmers attended resident practical training in sericulture including seed production at Bere Sericulture Production PLC. Practical bee colony multiplication on-site training was delivered to 510 (16% females) model youth, 115 experienced beekeeping farmers, 52 local extension staff, and the skill was demonstrated as a line of business for youth.	was very successful. The Mastercard Foundation was very supportive of this pilot hence this idea was taken up in the design of the MOYESH program which set out to partner with several large private commercial banks.
8.4 Market opportunities for youth in beekeeping and silk value chains created	• At least 70% of targeted youth in the project areas employed in the beekeeping and silk farming value chain in the period 2017–2020. • Youth led cooperatives established within the period 2017–2019. • 25% increase in honey and silk production by end of 2019 of the initial enterprises established. • At least two by- products introduced by end of 2019.	• Facilitate the establishment of legalized enterprises and cooperatives that are youth-led by early 2019. • Develop youth-led marketplaces for harvesting, bulking, processing (value addition) and packaging of quality honey and silk products by mid-2020. • Work with relevant Ethiopian Government organizations and NGOs to increase honey and silk market opportunities – import substitution and export promotion by end of 2020. • Facilitate the use of by-products of the silk and honey industries to	• By end of 2019, a total of 1049 youth led enterprises established, 884 in apiculture sites and 165 in sericulture sites. • Four honey and beeswax aggregation and processing marketplaces were established in 4 of the 12 project districts. Likewise, 4 sericulture marketplaces were set up to also serve as training and demonstration facilities. • With support of the EIF-WTO project on honey markets, the construction of 8 additional honey and beeswax marketplaces was completed at the end of 2019. Another apiculture marketplace was also established for one district of the Biovision supported pilot beekeeping project.	• To enhance benefits that accrue to project beneficiaries, as well as create additional indirect job opportunities, more technical and financial support is necessary to promote aggregation and value addition to primary products (crude honey, silkworm cocoons) through for instance complementary projects. This was taken up in the design of the MOYESH program and at least 40 such marketplaces will be

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
		benefit youth and their associations by end of 2020.		established under this program from 2020.
8.5 Learning among the project participants facilitated and key project learning captured and disseminated amongst the key stakeholders.	• M&E and outcome mapping strategy developed by end of 2017. • Document the extent to which beekeeping and silk farming are used for solving youth unemployment problem by 2019.	• Develop by 2017 a M&E plan for the project including a detailed learning plan to ensure uptake of the technologies by 2020. • Implement the M&E plan including baseline data collection and analysis, review and refinement of methodology after completion of cohort one and subsequent ongoing evaluation including end of project review during the period 2016–2020 • Develop an outcome mapping strategy including impact pathways in order to understand and document the impact generated by project implementation process during the period 2016–2020. • Monitor different partners (NGOs and Government Ministries) in order to document the extent to which beekeeping and silk farming are used for solving youth unemployment problem by 2020.	• Comprehensive M&E framework and plan developed, reviewed and adopted, with key strategic learning questions of the project incorporated. • Baseline and target production levels quantified based on data generated during 3 baseline surveys. • Two annual progress monitoring surveys conducted on the Year 1 and Year 3 cohort of youth enterprises and used to enrich of independent project mid-term evaluation report. • The independent midterm evaluation of the project was completed in at the end of 2018.	• The well set M&E framework and its implementation helped facilitate a more informative external midterm evaluation of progress of the project. • Findings and recommendations of the mid-term evaluation of the project were considered in the design of the MOYESH program to scale up gains made in the YESH project across the country.
8.6 Awareness raised and access to the outcomes and information on the project progress and achievements among project partners, relevant key stakeholders and the communities ensured.	• Project website developed by end of 2017 • Project progress review and planning meetings with key stakeholders for dissemination of reports • A communications plan developed by end of 2017. •	• Create by 2016 a project website for use as a dissemination vehicle for the wider audience, including project activities, progress and results; project publications and presentations. • Organize conferences and workshops to maximize the impact of dissemination and the sustainability of project outputs by 2020. • Develop a communication plan in order to identify relevant key stakeholders (internal and external) and enhance communication	• Project website initiated within the main *icipe* website, and the prototype was finalized for kick off; project communication staff attended brief training about the micro-site, but full implementation has not yet started. • Project communications officer recruited and engaged; the project communication plan was developed. • 5 model youth and 5 local beekeeping extension staff attended two national honey festivals; four honey festivals were organized at project sites, and each were attended by about 150 beekeeping youth, experienced beekeeping farmers, extension staff, traders and invited	

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
		among all parties involved in the project by 2017.	government officials; participants also visited successful youth beekeeping enterprises. • About 30 selected youth and 17 local extension staff were supported to take part in the Apimondia International Symposium and exhibition at the end of November 2018. • Four project flyers (2 in apiculture and 2 in sericulture) were prepared. Signages for training centres and project sites prepared; extension manuals and posters published and disseminated. Case stories prepared.	
Objective 9: 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.				
9.1. Assess of pollination efficiency of 10 stingless bee species and African honey bees in 7 greenhouse crops in Kenya.	• Pollination efficiency of seven stingless bee species and African honey bees assessed for seven horticulture crops in greenhouse in Kenya; • Plant-pollinator-microbe interaction a case study of 1 horticulture crop	• Fruits and seeds data records per tested crop species; • Nectar-dwelling micro-organisms data released for 1 ested crop; • At least one papers per crop prepared and submitted to international journals.	**i)** Fruits and seeds data for yellow bell pepper: i_1) 1 Msc student (Mr. Kevin Toroitich) selected from Embu University to conduct study on greenhouse watermelon pollination using stingless bee; i_2) Msc Proposal project submitted and approved by the University; i_3) Pollination efficiency of seven stingless bee species and *Apis mellifera scutelata* conducted on watermelon in green houses; i_4) bee foraging data, fruit and seeds quality data measured/recorded. **ii)** Fruits and seeds data for egg plants: ii_1) Pollination efficiency of seven stingless bee species and *Apis mellifera scutellata* conducted on Eggplant in green houses; i_2) bee foraging data, fruit and seeds quality data measured/recorded. iii) Plant-pollinator-microbe interaction conducted on greenhouse yellow bell pepper iii_1) Microbial species composition and floral nectar chemistry determined; iii_2) Manuscript under review.	• Aphids and white flies control are necessary to obtain successful plants; • More deep pollination study needed for M. bocandei, M. ferruginea and M. togoensis to assesstheir ability to do buzz pollination; • Most suppliers don't provide seeds of good germinatin rate • More data needed to be collected to assess the nectar microbe volatiles

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
			iv) At least one papers per crop prepared and submitted to international journals: iv_1) Watermelon pollination data analysis and one manuscript writing ongoing;	
9.2. Assess pollinator diversity of two Macadamia cultivar in three agro-ecological zones in Kenya.	• Pollinator diversity and their dynamics in two Macadamia cultivar assessed in Embu, Taita Taveta, and Kirinyaga in Kenya; • One MSc student	• Pollinator species diversity records per seasonal flowering periods. • At least one paper prepared and submitted to international journals. • One MSc student thesis on Macadamia pollinators in Kenya.	i) Pollinator species diversity records per seasonal flowering periods: I_1) Pollinators have been collected at the 3 sites during Macadamia low and high flowering seasons; I_2) Specimen collected have been identified to species level; I_3) 8 Pollination treatments have been set in field to compare nut production and quality; I_4) Data on flowers number per raceme, initial nut set per pollination treatment had been collected and recorded. ii) At least one paper prepared and submitted to international journals: ii_1) Pollinators data being updated. ii_2) One manuscript writing ongoing for Introduction, material and methods. iii) One MSc student thesis on Macadamia pollinators in Kenya: The temporary technician who was working of the subject for his MSc quitted for another project	• For such type of field work, task must be assigned to a technical staff who can work under pressure and hardship conditions. Otherwise the selected person will discontinue working on the tasks
9.3. Assess stingless bee species using species distribution modelling.	• Assessment of distribution due to agro-ecological zone to inform species conservation measures.	• Species distribution models provided for project countries. • Establish training Centre in Kenya for stingless bees farming activities by 2021. • At least one paper prepared and submitted to international journals.	i)Species distribution models provided for project countries: i_1) 1 Msc student (Mr. Eliott Deprins) selected from Universite Libre de Bruxelle in Belgium to conduct study; i_2) Msc Proposal project submitted and approved by the University; i_3) Eliott Depris completed and submitted his Msc thesis Title: *Les melipones en afrique subsaharienne : analyse de miels, aperçu de leurs usages traditionnels et étude de leur distribution spatiale*.	

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
			iii) Establish training Centre in Kenya for stingless bees farming activities by 2021: ii1) More than 300 hives have been nested with different stingless bee species and are waiting to be set at the site of the center once established ii2) Land negotiation at the edge of Ikuywa forest station in Kakamega still ongoing with Kenya Forest Services **iv)** At least one paper prepared and submitted to international journals: One manuscript under review	
9.4. Assess genetic diversity of African stingless bees using DNA barcoding and morphometric analysis.	Species discrimination base of morphometric, genetic differentiation and species phylogeny of some African stingless bee species scientifically available by 2019.	• Wing geometric morphometric of African stingless bee species provided. • Molecular barcodes of African stingless bee species provided. • Booklet on African stingless bees. • At least one papers prepared and submitted to international journals.	-Pinning and labelling 30 stingless bee samples from Gabon and Burkina faso i) Wing geometric morphometric of African stingless bee species provided: i_1) wing geometric morphometrics conducted on 325 colonies samples; i_2) PCA and CVA results for the large stingless bee species from different coutries have been provided. **ii) Molecular barcodes of African stingless bee species provided:** $ii_{1)}$ Macrogen account open for sequencing 200 bee samples; ii_2) Updated 174 sequenced samples; ii_3) The tree for 150 sequenced samples have been drawn ii_3) stingless bee row data sheet updated with 617 samples **iii) Booklet on African stingless bees:** • Draft version in progress. **iv) At least one papers prepared and submitted to international journals:** • Two manuscripts under review • 1 MSc thesis (Miss Sabine Nansong) from University of Dschang in Cameroon completed:	• The delay in obtaining the DNA molecular analysis kit from the supplier negatively impacted the work progress.

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
			Title: Species diversity and Biometric biodiversity of stingless bees in the western highlands of Cameroon.	
9.5. Capacity building of stakeholders in meliponiculture.	• Training of at least one ToT from DR Congo, Kenya, Cameroon, Botswana and Ethiopia.	• List of trained people.	• 20 people trained in Kenya (13 men, 7 ladies); • 17 people trained in Burkina faso (16 men, 1 ladies); • 22 people trained in Cameroon (15 men, 7 ladies) • people trained in Kenya (4 men, 1 ladies) • Training of wild fauna focal point from 23 francophone African countries	• High interest by stakeholder • More grant needed to outreach a large number of peoples
9.6. Capacity building for pollination efficiency evaluation for *icipe* postdoc staff.	• One *icipe* postdoc staff scaled up on pollination knowledge from an European Research Institution.	• One post doc staff trained in pollination.	• Undergoing through the divers pollination experiments being conducted in this project	
9.7 Capacity building of university students on conducting pollination efficiency evaluation studies.	• Training of at least five University students (BSc or Master level).	• List of students on attachment.	• 1 Bsc student (Mr. Junior Kika) from Kenyatta University trained on greenhouse cucmber pollination using stingless bees; • 1 Msc student (Mr. Kevin Toroitich) from Embu University undergoing training on greenhouse watermelon pollination using stingless bee; • 1 PhD student (Miss Regina Waiganjo) from Kenyatta University undergoing training on greenhouse strawberry pollination using stingless bee; • 1 Msc student (Mr. James Kamau) from Kenyatta University undergoing training on greenhouse Eggplants pollination using stingless bee.	• Students need more time to achieve their writing of Msc and publications
Objective 10: 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)				
10.1Establish partnerships and identify and develop resources for scaling up beekeeping and silk farming enterprises to increase employment and learning	• 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.		

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
opportunities for youths (PARTNERSHIP AND RESOURCES MOBILIZATION).				
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.		
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.		
Develop skills and capacity of youth and partners to undertake and manage successful and sustainable beekeeping and silk	• 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		

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
enterprises as 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.	youth to 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).		
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.		
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. • Program achievements and best practices documented and disseminated.	• 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 disseminated (leaflets, banners, etc.).		

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
	• 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.	• 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 11: Investigate the ecology and evolution of on sub-Saharan African stingless bees by 2024				
11.1. Analyse the physical chemical and bifunctional characterization of African stingless honey compared to honey produced by the Western honeybee, *Apis mellifera* (Hym. Apidae, tribe Apini).	• Chemical composition and. bifunctional properties of various African stingless bees known and published.	• One Msc and PhD staff trained. • 2 publications.	• 1 Msc student thesis completed by Mr. Eliott Deprins at Universite Libre de Bruxelle in Belgium. • Title: Les melipones en afrique subsaharienne : analyse de miels, aperçu de leurs usages traditionnels et étude de leur distribution spatiale. • -PhD fellowship for studying the ecology and evolution of stingless bees advertised. • 210 honey samples analysed so far for physico chemical and biofunctional properties.	• More training to be provided to students
Objective 12: Participatory beekeeping for ecological protection of Mangrove forests in Zanzibar (ZanBee) (Biovision)				
12.1 To develop a mutual link between beekeeping and environment for improved honey production, through promotion of	• Increase to 25% of beekeepers engaged in other environmental activities.	• Number of beekeepers who are engaged in environmental activities		

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
multipurpose and all-season nectar and pollen supply plants through community nurseries and training.	• 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.	• availability of forage plants over the whole year. • Number of products derived from beneficial trees produced.		
12.2 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). • Increase of high quality of honey produced by 80% of farmers. • 50% of participating farmers keep records of the health of their bees.	• kg of honey produced. • Quality of honey produced. • Availability of information on bee health (provided by beekeepers).		
12.3 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.		
Objective 13: Alternative Livelihoods for Food and Income Security in Four Indian Ocean Island Nations (Seychelles, Mauritius, Comoros, Madagascar) and Zanzibar (Republic of Tanzania) – Phase II				
13.1 Scale up and consolidate gains in improved beekeeping technologies for adoption by smallholder farmers for increased production of honey and other hive products.	• Increased adoption of modern beekeeping technologies and improved hives by at least 80% of the targeted smallholder farmers.	• At least 80% of beneficiaries have adopted modern beekeeping technologies. • 800 farmers have improved hives. • At least 20-25% increase in honey production.	• 400 modern hives supplied (60 in Zanzibar; 40 in Seychelles and 300 in Mauritius) plus accessories like smokers and protective suits. • 681 (210 in Zanzibar; 200 in Madagascar and 281 in Mauritius) farmers trained on improved beekeeping technologies. • 114 beneficiaries (including beekeepers, Ministry staff and officials of Beekeeper Associations) trained on Mobile Data Collection (Open Data Kit) for monitoring of hive performance in Zanzibar and Madagascar.	• Capacity for local production of modern hives is still very low in Comoros and needs to be improved. • Skilled beekeepers trained in Phase I playing a critical role in extension support to untrained beekeepers.

Outputs	***Outcomes***	***Performance Indicator***	***2019 Progress in Achieving Outcomes***	***2019 Lessons Learned***
13.2 Disseminate proven options and approaches for marketing honey by strengthening the capacity of farmers 'organizations.	• Increased incomes of targeted smallholder households from honey and hive-based products as an alternative source of income for reduced vulnerability to shocks inherent in targeted Island Nations.	• Completion and operationalization of 5 fully equipped marketplaces for processing honey and hive-based products. • Completion of 5 honey collection centres. • 1,000 farmers aware of organic beekeeping standards. • 30% increase in price of value-added honey sold by targeted farmers.	• Post-harvest equipment for collection centers procured for Zanzibar, Seychelles and Madagascar. • Land identified and allocated for construction of collection centers in Seychelles and Zanzibar. • 49 beneficiaries (29 beekeepers; 16 government staff and 4 officials from Beekeepers Associations) trained on Internal Control System (ICS) for organic honey production in Zanzibar and Madagascar.	• Line Ministries or Departments need to work closely with Beekeeper Associations to achieve full potential of the honey marketplaces.
13.3 Strengthen the capacity of key partner institutions to deal with critical emerging issues affecting the beekeeping sector such as bee health, land degradation and climate change, and to influence formulation and implementation of strategies that promote sustainable.	• Enhanced capacity of partner institutions on issues, thematic areas and approaches for consideration in formulation and implementation of strategies/policies for bee health and sustainable growth of beekeeping industry.	• 25 staff members of key institutions in targeted Island Nations trained on improved technologies in beekeeping • 5 beekeeping resource centres supported. • Manuals on honeybee health, pollination services and honey quality developed and other beekeeping resource. documents revised for dissemination • 100,000 key stakeholders in beekeeping industry in targeted Island Nations reached with information on improved beekeeping	• 8 lead trainers (2 each from Comoros, Zanzibar, Seychelles and Madagascar) trained on diagnosis and control of key honeybee pests and diseases and honey quality control. • 12 extension staff from Zanzibar and Madagascar trained on improved beekeeping technologies. • 8 extension staff from Zanzibar and Madagascar trained on honey and beeswax post- harvest technologies.	• Wide stakeholder consultation is key in the formulation of policies. For example bee keepers have not adopted the bee reserves/zones in Mauritius due to fear of theft of hives/honey.
Specific Objective 14: To enhance productivity of avocado and cucurbits among smallholder growers in East Africa through integrated pest and pollinators management (IPPM)				
14.1 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.	• Symbionts in key pests and pollinators of cucurbits and avocado characterized by 2019.	• Honey Bee gut symbionts characterized. • Research publication. • Stingless bee gut symbionts characterization on-going.	• Underestimated amount of work to characterize pest symbionts and the gut microbiota expert was based 6 months abroad. It is unlikely that this data will be generated.

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
14.2 Strengthen capacity, transfer technology and create policy awareness on IPM-pollination integration.	• A cohort of trained young scientists created.	• At least 3 PhD and 2 MSc students trained on bee symbionts, integration of IPM with pollination services and GIS/earth observation tools by end of 2020.	• 1 MSc thesis planned for 09/2020. • 1 PhD thesis. planned for 09/2020.	
14.3 Apis mellifera and Stingless bee gut characterization in Africa.	• First characterization of *Apis mellifera* gut microbiota in Africa. • Identification of protective gut microbiota. • Set up the protocols and the conditions to sample Stingless bees based on the work on the honey bee.	• Publications. • Establishment of a bacterial library. • 16S rRNA sequences data • Establishment of survival. and colonization protocols.	• One article published. • A second article in almost ready to be submitted. • Stingless bees samples are ready for analysis. • 1 Master and 1 PhD thesis in progress (expected to graduate mid 2020).	

7.6 Social Science and Impact Assessment Unit: Results Based Management (RBM) Rolling Framework Report

Outputs	Outcomes	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	2019 Lessons Learnt
NAME of Project: The African Fruit Fly Programme:				
Objective 1: Assess the spillover effects of mango IPM fruit fly control technology on farm productivity and health and environment effect of the IPM in Kenya				
Economic spillover effects of mango IPM fruit fly control technology on farm productivity evaluated.	• At least 3000 households are aware of the spillover effects of mango IPM fruit fly control technology on.	• One field survey conducted in one of the Kenyan sites. • One MSC thesis produced by April 2015. • At least one journal article produced by end of 2015	• MSc student graduated on 6th September 2019 with Msc.in Agricultural Economics, University of Nairobi • One Manuscript published. "Githiomi, C., Muriithi, B., Irungu, P., Mwungu, C. M., Diiro, G., Affognon, H., ... & Ekesi, S. (2019). Economic analysis of spillover effects of an integrated pest management (IPM) strategy for suppression of mango fruit fly in Kenya. *Food policy, 84, 121-132.*	• Positive fruit fly IPM spillovers at farm-level revealed especially among farmers who grow pawpaw and citrus in addition to mangoes.
Economic analysis of health and environmental benefits of fruit fly IPM technology evaluated.	• At least 3000 households are aware of the health and environmental effects of fruit fly IPM technology in Kenya and the results disseminated to other countries' project sites and project partners	• One field survey conducted in one of the Kenyan sites. • One MSC thesis produced by end of 2015. • At least one journal article produced by end of 2015.	• Midingoyi, S-K, G., Kassie, M., Muriithi, B., Diiro, G. and Ekesi, S. (2019). Do farmers and the environment benefit from adopting integrated pest management practices? Evidence from Kenya. *Journal of Agricultural Economics*, 70(2): pp. 452-470.	• Adoption of the fruit fly IPM strategy reduce health and environmental risks. Greater economic, health and environmental benefits achieved when IPM practices adopted in combination than individually.
Objective 2: Beyond mango fruit fly control: The impact of IPM technology for mango fruit fly control on Food security, gender and intra-household dynamics				
Impact of fruit fly IPM strategy on food security among smallholders in Kenya determined.	• At least 3000 households aware of the effects of the fruit fly IPM on their food security status	• One Follow-up survey conducted in previously surveyed sites in Kenya by end of 2017 • One Msc thesis produced by end of 2018 • At least one journal article produced by end of 2018	• One manuscript published "Nyang'au P., Muriithi B., Nzuma J., Irungu P., Gichungi H., & Diiro G. (March 2020). Impact of integrated pest management strategy on food security among smallholders in Kenya. *AJFAND,* 20(2), 15431-15454.	• Using two-wave panel dataset from Machakos County Kenya, the study revealed that fruit fly IPM users had a positive impact on per capita calorie intake but no significant effect on Household Dietary Diversity Index (HDDI)
Effect of fruit fly IPM Technology on Gender roles and intra-household dynamics among smallholder mango producers in Kenya determined.	• At least 3000 households and other mango value chain actors aware of the effects of the fruit fly IPM on women's decision making in mango production and marketing in Kenya	• One Follow-up survey conducted in previously surveyed sites in Kenya by end of 2017 • One Msc thesis produced by end of 2018	• One draft thesis produced and submitted for examination, at the Department of Agricultural Economics and Agribusiness management, University of Nairobi. • One manuscript accepted for publication "Gichungi, H., Muriithi B., Irungu P., Diiro G., & Busenei J. Impact of integrated pest management strategy on food security	• Using a panel dataset of 600 mango growing households obtained from Machakos county, the study showed that the proportion of women involved in decision making decreased in 9 of the 13-mango production and marketing decisions, but no

		• At least one journal article produced by end of 2018.	among smallholders in Kenya. In press, *European Journal of Development Research.*	gender heterogeneity when we controlled for farm, household and information characteristics. Women's decision-making index in mango production and marketing can be enhanced through access to training, membership to a mango production or marketing group, and access to credit.
NAME of Project: Integrated Vector Management (IVM) for Sustainable Malaria Control in Eastern Africa				
Objective 1: Assess the impact of the IVM strategies on communities' health, and livelihood.				
Assess the willingness to Pay (WTP) for Community-level Larviciding using Biopesticides.	• Stakeholders and partners made aware of the community members' willingness to pay for Larviciding biopesticides.	• At least one (1) research report produced by end 2018.	• One draft manuscript submitted for peer review, "Willingness to Pay for Community-level Malaria vector control: An auction Experiment of Mosquito Larviciding using Biopesticides in Kenya" submitted to *Environmental and Sustainability Indicators.* • Randomized Controlled trails studies on house screening in combination with push-pull technology and community mobilization impact on socio-economics is underway in Ethiopia and Zambia.	• The results showed high market potential for UZIMAX. Nearly all respondents were WTP at the lowest bid price of Ksh 395 ($3.95). The results also show opportunity for collective engagements in the fight against malaria based on participants' increased interest in contributing money towards Larviciding in their villages (by 97%), and time (labour) to apply the bio-pesticide in their village.
NAME of Project: Multi-Intervention Impact Assessment 4-H Project (H for Health) in Tolay (Ethiopia)				
Objective 1: Assess and compare the impact of combined 4-H interventions to single H or 2-H or 3-H interventions on household income per capita in Tolay (Ethiopia).				
Objective 1.1 To evaluate the impact of combined 4-H interventions.				
The impacts of combined 4-H, single H, 2-H and 3-H interventions on household income per capita in Tolay (Ethiopia) are	• One impact assessment report utilised by donor by end of September 2014.	• At least one (1) research report and one draft journal article bent by end of 2014.	• Manuscript published "Kassie, M., Abro, Z., Wossen, T., T Ledermann, S., Diiro, G., Ballo, S., & Belayhun, L. (2020). Integrated Health Interventions for Improved Livelihoods: A Case Study in Ethiopia. *Sustainability,* 12(6), 2284.	• This paper examined the economic implication of four ecological interventions introduced in a pilot study in rural Ethiopia to control trypanosomiasis, malaria and stemborers, in addition to apiculture. simulation results from the study demonstrate that all

assessed and compared.				interventions individually lead to substantial increase in discounted net income and resources productivity by 11 to 94% compared to the baseline farming system. However, the additional per capita income due to prompting the 4H interventions jointly is 33 percent higher than the interventions are introduced individually, suggesting synergetic benefits of interventions.
NAME of Project: Integrated pest management strategy to counter the threat of invasive fall armyworm to food security in eastern Africa (FAW-IPM)-				
Objective 1: Livelihood, environmental and gender impacts of FAW along the maize value chain in East Africa determined and utilized for decision making				
Understand Knowledge, Attitudes and Practices (KAP) and the enabling policy related to FAW.	• Stakeholders are aware of current knowledge and management practices of FAW and available policies.	• One paper documenting information about current knowledge and management practices of FAW by stakeholders and enabling policies.	• Paper published on farmers current management; and knowledge of FAW and impact using data from Ethiopia: • Kassie, M., Tesfamicheal, W., De Groote, H., Tefera, T., Sevgan, S. and Balew, S. (2020) Economic impacts of fall armyworm and its management strategies in Southern Ethiopia. European Review of Agricultural Economics. pp. 1-20. doi:10.1093/erae/jbz048. • Protocol developed to guide community level assessment of spread and impact of FAW in Uganda. • Focus group discussion (FGD) and Key informant (KI) interviews conducted to understand FAW impact in Uganda. • The FGD and KI interview cover (202 sex disaggregated FDGs; 45 extension workers and 25 input dealers.	
Quantify the economic impacts of FAW damage for the different social groups.	• Stakeholder aware economic burden of FAW and make informed decision on control and management of FAW.	• A paper documenting evidence on economic burden of FAW.	• Two papers published on economic impact of FAW and its management strategies. • De Groote, H., Kinenju, S.C., Munyua, B., Palmasa, S., Kassie, M., Bruce, A. (2020). Spread and impact of fall armyworm (Spodoptera frugiperda J.E. Smith) in maize production areas of Kenya. *Agriculture, Ecosystems & Environment*, 292, 106804. • Kassie, M., Tesfamicheal, W., De Groote, H., Tefera, T., Sevgan, S. and Balew, S. (2020) Economic impacts of fall armyworm and its management strategies in Southern Ethiopia. *European Review of Agricultural Economics*. pp. 1-20. doi:10.1093/erae/jbz048.	

Establish the economic, environmental, nutrition, and human health impacts of pesticides use and the various biological control (BC) methods	• Policy makers and development partners use better evidence in decision making to diffuse biological control of FAW	• One paper on economic, environmental and nutrition impacts of BC	• -Developed a protocol "Evaluating cost-effectiveness of FAW-IPM to control FAW" to guide the evaluation in Uganda. • Conducted a baseline survey of 108 maize farmers (60% push-pull users) selected from 6 districts in Uganda for testing the effectiveness of IPM for FAW control. • Survey instrument developed to establish the economic, environmental, and nutrition impact of interventions in Ethiopia, but survey implementation postponed due to COVID-19.	
NAME of Project: Integrated pest and pollinators management (IPPM) to enhance productivity of avocado and cucurbits among smallholder growers in East Africa				
Objective 1: Impacts of integrating pollination services and Integrated Pest Management (IPPM) on farmers' livelihoods determined				
Assess the Knowledge, Attitude and Practices (KAP) towards integrating pollination services and IPM	• Enhanced information about farmers' KAP of pollination services and IPM.	• Msc proposal by end of 2018. • At least one working paper on KAP by end of 2019.	• -One MSc student graduated, with Msc. Economics, University of Nairobi. • -Baseline survey data collected among 410 avocado farmers in Kenya. • -Draft manuscript produced *"Farmers Knowledge and perception, and Willingness to Pay for an Integrated Pest and Pollinator Management (IPPM) Innovation in Murang'a County, Kenya".*	• The study assessed farmer's knowledge, attitude and practices towards integrating pollination services and IPM strategies (IPPM) and estimated the potential demand for IPPM among avocado farmers in Murang'a County, Kenya. Although knowledge gap was observed, farmers depicted positive WTP for the innovation.
Estimate ex-ante adoption of IPM pollination services in the target countries	• Improved evidence on potential adoption of IPPM.	• At least one paper on ex-assessment of demand for IPPM by end of 2019. • MSc thesis by end of 2019.	• As above, potential demand captured in this paper • Second draft paper produced "The economic impact of integrating pests and pollinators management strategies in avocado farming, Kenya and Tanzania; An ex-ante Analysis".	• The second paper analyses the potential economic impact of integrating non-pesticides control measures with pollinators. The study revealed positive return to IPPM investment.
Determine impact of IPPM interventions on livelihoods of avocado and cucurbits producers	• Policy makers and partners use evidence Improved evidence and knowledge on impacts of IPPM.	• Peer reviewed paper on impact of combination of pollination services and IPM.	• Baseline data collected from 410 and 420 avocado growers in Kenya and Tanzania respectively and 90 cucurbit growers in Kenya.	
NAME of Project: Biovision Rift-Valley Fever (RVF) research project in Garbatulla sub-county, Isiolo, Kenya				
The impact of training of the RVF implemented training on change in knowledge	• Policy makers and partners have evidence on the impact of stakeholders training on their RVF knowledge and	• One Report on impact of community training on behavior towards RVF.	• Working paper published: Midingoyi, S-K, G., and Kassie, M. (2019). The impact of Rift-Valley Fever (RVF) training program on knowledge, attitudes and practices in pastoral communities of Kenya.	• Using two rounds of panel data, we estimate the causal impact of the training on knowledge, practices and attitudes (KAP) using difference-in-difference. The

attitude and behavior regarding RVF among the study communities assessed and documented	behavioural change regarding RVF.			findings of the study reveal that RVF training program play a significant role in reducing human and economic losses caused by RVF. It improves KAP by 20 percentage points, which is a significant progress in limited period. However, still there prevail scopes for further improvement as the total KAP scores were not achieved. Repeated training should be considered to achieve total KAP that will ensure the prevention and management of the disease during outbreaks.
NAMEE of Project: Project Name: Three diseases, One Health; A one health, participatory approach to combating a complex of zoonotic diseases in northern Kenya				
Community awareness and practical knowledge on disease risk, prevention and control assessed	• Stakeholders are aware of the community knowledge, beliefs and behaviors towards RVF, leishmaniasis and brucellosis.	• One report on community knowledge Awareness and practical knowledge on disease risk, prevention and control.	• A follow survey was conducted in November 2019 • A draft manuscript has been produced "Effect of One health approach on local community's Knowledge, Attitude and practices: A case study of Rift valley fever, Brucellosis and Leishmanisasis diseases in Northern Kenya".	• The results show that many farmers are not aware of the major risks associated RVF, leishmaniasis and brucellosis.
NAME of Project: Integrated Biological Control Applied Research Programme (IBCARP)				
Objective 1: Adoption and socio-economic impact assessment of fruit fly IPM				
Farmers' Knowledge and Perceptions on fruit flies and Willingness to Pay for a fruit fly IPM Strategy in Gamo Gofa Region, Ethiopia.	• Development partners aware of farmer's knowledge and perceptions on fruit flies and WTP for fruit fly IPM.	• At least one peer reviewed paper.	• One working paper produced and submitted for peer review; Farmers' Knowledge and Perceptions on fruit flies and Willingness to Pay for a fruit fly Integrated Pest Management Strategy in Gamo Gofa Zone, Ethiopia. Under review with *International Journal of Agricultural Sustainability.*	• Despite limited knowledge of the IPM technologies, majority of the mango growers are willing to buy the fruit fly package to reduce their produce losses and increase their income.
Adoption of Integrated Pest Management Strategy for Suppression of Mango Fruit flies East Africa): An ex ante and ex post	• Development partners and other stakeholders aware of farmer's adoption of IPM strategy	• At least one peer reviewed paper.	• One working paper produced, presented at the 6th African Conference of Agricultural Economists (6thACAE) in Abuja, Federal Capital Territory, Nigeria, 23 – 26 September 2019, and submitted for peer review, "Adoption of Integrated Pest Management Strategy for Suppression of Mango Fruit flies in East Africa: An ex-ante and ex-post analysis in Ethiopia and Kenya". Submitted to *Agribusiness Journal.*	• Enhanced awareness/exposure can accelerate adoption of the IPM technologies among horticultural farmers in East Africa (using a case of Kenya and Ethiopia).

analysis in Ethiopia and Kenya				
Potential socioeconomic benefits of controlling mango-infesting fruit flies and returns to Integrated Pest Management research in Kenya	• Farmers, development partners and other stakeholders made aware of the potential socio-economic benefits of fruit fly IPM in Kenya	• At least one peer reviewed paper	• One manuscript produced (under review) • Farmers interviewed at baseline in Ethiopia revisited to assess the impact of IPM training on knowledge and perception of IPM products, demand for the products, mango yield loss and use of pesticides.	• Fruit fly IPM research in Kenya can derive economic surplus benefits of about US$ 18.79 million every year. Assuming a maximum adoption level of 50%, and discount rate of 7%, net present value of the fruit fly IPM research is about US$ 75 million (US$2.35 million per year), with an internal rate of return (IRR) of 29% and benefit-cost ratio US$27:1.
Assessment of the effect of Fruit Fly IPM use on Mango Value Chain in Elgeyo Marakwet County, Kenya.	• Development partners and other stakeholders aware of the effects of fruit fly IPM training on mango value chain in Eleyo Marakwet County.	• Panel dataset • At least one peer reviewed paper	• A third follow-up survey was conducted in 2019; An Msc thesis was produced and submitted for examination; *"*Economic Assessment of training and use of Integrated Fruit Fly Management Strategy among Mango Farmers in Elgeyo Marakwet, Kenya"*,* • A draft manuscript has also been produced from the panel dataset	• The RCT study seek to assess the impact of training and use of fruit fly IPM among mango growers in Kenya. The results indicate that those that received IPM training and IPM materials had significant improvement in their knowledge and perception on IPM use, and reduced fruit fly infestation and pesticide expenditure.
Objective 2: Tsetse collar component: Up-scaled and adapted tsetse repellent technology ready for roll-out to African countries				
Impact assessment of tsetse collar in management of tsetse flies and trypanosomiasis.	• Economic benefits of tsetse collar in management of tsetse flies and trypanosomiasis established and shared with stakeholders.	• One focus group report by end of 2017.	• One draft paper produced "Knowledge, Perceptions, and Willingness to Pay for a Tsetse and Trypanosomiasis Control among Smallholder Livestock Farmers in Kwale County."" • Expert survey on tsetse fly and trypanosomiasis parameters in sub-Saharan Africa conducted in collaboration with the African Union – Pan African Tsetse and Trypanosomiasis Eradication Campaign (AU-PATTEC). • Using data from various sources a draft paper entitled 'Economic benefits of controlling trypanosomiasis using repellent collar technology (TRCT) in sub-Saharan Africa' finalized.	• Majority of the farmers in Kwale use trypanocides to manage tsetse and tryps, with good diagnosis knowledge, and were willing to buy icipe tsetse repellant collars once they are made available in the market. • The expert survey reveals that quality data on key economic parameters on tsetse fly distributions and interventions are largely unavailable. This suggests the importance of collecting quality data to develop integrated decision-making modeling tools for the evaluation of tsetse fly control technologies.

				• The findings of the draft paper show that a 5 to 15% adoption of tsetse fly repellent collar technology (TRCT) would generate an economic surplus of US$57–176 million per annum for 18 countries in sub-Saharan Africa. The estimated benefit cost ratios (4:1) further show that the technology is worthy of investing in. these benefits are likely underestimated because our estimates do not include draught power services of animals and the increase in productivity of human labor. These benefits seem to suggest that investing in TRCT may contribute to the sustainable development goals.
NAME of Project: Leap-Agri Sustainable intensification of fruit production systems through innovative pest biocontrol technologies (Pest-free fruit)				
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.	• One baseline survey in at least two sites in Kenya and Senegal by end of 2019. • At least one working paper by mid-2020.	• Baseline survey consisting of 165 mango growing households conducted in Embu county, Kenya • Draft manuscript produced *"Barriers and opportunities for scaling up sustainable agricultural innovations: A case of fruit fly IPM technologies in the Kenyan Mango Farming Systems".*	• The study seeks to track farmer's innovations in management of invasive fruit flies and access their adoption of an IPM approach developed and promoted by icipe. The findings reveal that, although farmers are aware and some use the IPM technologies, they still heavily depend on synthetic pesticides (90%), as well as indigenous methods (35%) to manage the pest.
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 in at least two sites in Kenya and Senegal by end of 2021. • At least one peer review manuscript by end of 2021.	• -Baseline survey that will provide the benchmark for impact assessment was conducted as above.	
NAME of Project: Combating Arthropod Pests for Better Health, Food and Resilience to Climate Change (CAP-Africa)				
Objective 1: Test innovative approaches for stimulating increased adoption and impact of push pull technology (PPT)				

The role of social learning on adoption of PPT determined and documented.	• Policy makers and development agents have improved understanding and knowledge of social learning as a strategy for stimulating technology adoption.	• Working paper on the effect of social learning on adoption of PPT by gender groups (men and women).	• Impact evaluation protocols developed both for Ethiopia and Uganda Randomized Controlled trial (RCT) studies to understand role of social network and subsidies on technology up-take and knowledge diffusion. • Baseline survey report for the CAP Africa Project in Ethiopia prepared. • A baseline survey conducted in Uganda and Ethiopia from 902, and 3,000 farm households, respectively. • 428 farmers and 200 agricultural experts trained on PPT in Ethiopia to facilitate establishment of RCT. • Conducted 2-days training of Trainers of trainers and lead farmers (106 ToTs, 50% female) on Push Pull technology (PPT) establishment and management in Uganda. • ToTs trained 655 individual farmers on FAW, striga, stemborer and their management, with focus on Push-Pull farming system (PPT) establishment and management in Uganda. • Recruited two technicians in the study areas to facilitate establishment of farmer's PPT plots (Uganda). • Registered an RCT study to measure the effect of credit subsidy schemes and performance rewards (incentives) on technology take-Up and subsequent investment decisions. https://www.socialscienceregistry.org/trials/5643 • Registered an RCT study to the role of social network, incentive and nudge on knowledge diffusion and push-pull technology adoption, as well as house screening effect on health and malaria prevalence. (https://www.socialscienceregistry.org/trials/5642) • Focus group discussion to understand the gender needs conducted in Ethiopia, Kenya, Uganda and Tanzania.	• Farmers, development agents, experts and politicians at different levels of the regional government understood PPT. They are also promoting PPT diffusion. The trainings and discussions with local experts also indicated the importance of coordinating activities with local partners for PPT adoption. • Having an impact evaluation protocol before starting project interventions and data collection greatly facilitated and speeded up project activities. It helped to create common understanding among research team members and partners. • The gender needs assessment report shows that female-headed households and women irrespective of the household type are disproportionately affected by malaria, and absence of improved technologies in agricultural production. The research team and partners agreed to target women in the project activities in 2020.
Impacts of PPT adoption on maize and milk productivity, household food security, and income determined.	• Enhanced knowledge policy makers and partners on milk productivity, household food security, and income determined.	• Working paper on the impacts of PPT adoption on maize and milk productivity, household food security, and income	• RCT experiment is on-going.	• NA
Production risk impact of PPT adoption determined and documented.	• Enhanced knowledge of policy makers and partners on the production risk implications of PPT adoption.	• Peer-reviewed paper on PPT adoption and agricultural productivity risk	• Ongoing.	• NA

Effect of PPT on Women's labor supply and dietary diversity of women & children determined.	• Policy makers and development partners have improved evidence and enhanced knowledge on the gender differentiated impacts of PPT adoption.	• Working paper on labor allocation impact of PPT Working paper on PPT and women's empowerment.	• Working papers produced • Diiro, G., Fisher, M., Muriithi, B., Kassie, M. & Muricho, G. (2020). The Impact of push-pull technology (PPT) adoption on women's and men's labour and social investment in Kenya. • Kassie, M., Fisher, M., Diiro, G., and Murichio, G. Women's Empowerment Boosts the Gains in Dietary Diversity from Agricultural Technology Adoption in Rural Kenya.	• The results show that PPT adoption significantly reduces labor requirements during ploughing, weeding and threshing but significantly increases labor for harvesting. In comparison to men, women save more labor hours, as a result of PPT adoption, during weeding and threshing but less during ploughing. These findings point suggest that scaling up PPT can generate livelihood opportunities, increase productivity, food security and enhance human capital development in rural economies, especially those that rely on cereal crop enterprises. • On nutrition role of PPT, we demonstrate it has a positive impact on women's dietary diversity regardless of women's empowerment status, its effect is stronger for households with empowered vs. disempowered women.
Objective 2: Establish the economic burden of malaria and livelihood impacts of IVM interventions for malaria prevention and control among rural households				
Assess the gender differential impact of malaria on labor productivity, and income determined.	• Policy makers and development partners have enhanced knowledge on the gender differentiated impacts of malaria burden in rural households.	• One paper on impact of malaria on labor. • supply and income.	• Ongoing.	• NA
Impacts of IVM intervention strategies on household health and Economic welfare determined.	• Policy makers and development partners have enhanced knowledge on livelihood impacts of implementing IVM strategies.	• One papers on IVM intervention impact on household health and economic welfare.	• Randomized controlled trial is ongoing in Ethiopia.	• NA
Objective 3: Developed and operationalize Performance, Monitoring, and evaluation framework (PME) for the project to facilitate learning, monitoring and dissemination of lessons learned				

Fine-tuning of the result framework through consultation of host country partners, project staff, and participation of M&E specialist in inception workshops.	• A common result framework adopted by the project partners and staff.	• One M & E plan that can be revised based on feedback from partners produced and lessons learned.	• M&E framework revised.	• NA
M&E specialist trains researchers from host countries and project staff in implementing common result framework;	• Enhanced knowledge and appreciation of the common result framework by researchers and project staff.	• 20 stakeholders trained in M&E aspects and tools.	• On-going.	• NA
NAME of Project: *icipe* technologies and gender impact and M&E strategy document				
Objective 1: Assess adoption of push-pull technology impact on farm- and aggregate- level impacts				
Evaluate effects of push-pull technology (PPT) in Kenya and Uganda.	• Enhanced evidence on performance of PPT.	• Two papers on impacts of PPT.	• One impact paper published: Kassie, M., Stage, J., Diiro, G., Muriithi, B., Muricho, G., Ledermann, S.T., Pittchar, P., Midega, C., and Khan, Z. (2018). push–pull farming system in Kenya: Implications for economic and social welfare. *Land Use Policy*, 77, PP.186-198..	• We observe that the adoption of PPT led to significant increases in maize yield and net maize income. The technology has significant potential benefit in terms of increasing economic surplus and reducing the number of people considered poor in western Kenya. Important factors influencing the decision to adopt PPT included access to information, household education, social capital, and social networks. We conclude that effective policies and development programmes for pro promoting PPT in Kenya should include information delivery and education mechanisms that are more effective.
Assess the impact of Push-Pull technology on	• Enhanced evidence of PPT on households .	• Manuscript on the adoption and willingness to pay of	• Saliou Niassy, Michael Kidoido, Nyang'au Isaac Mbeche, Jimmy Pittchar, Girma Hailu, Rachel Owino, David Amudavi and Zeyaur Khan (2020). Adoption and	• The study shows that household heads with spouses who belong to farmer groups or receive extension

household livelihoods in Rwanda.		PPT among smallholder maize farmers in Rwanda .	willingness to pay for Push-Pull Technology among smallholder maize farmers in Rwanda. *International Journal of Agricultural Extension and Rural Development*. ISSN 3254-5428 Vol. 8 (1), pp. 001-005.	support for crop production were likely to adopt PPT. Regarding willingness to pay for PPT, the study finds that farmers who were resource constrained, for instance those needing credit for crop production and living relatively far away from input stockists, were less likely to pay for PPT. Whereas, farmers with livestock or who were receiving extension support for crop production were more likely to pay for PPT. The imply that farmers' decisions to adopt and pay for PPT depend on their socio-economic circumstances and performance of the technology.
Web-based Planning, Monitoring, Evaluation and Learning system designed and implemented	• *Icipe* performance and impact is well monitored and documented	• Functional online PMEL data collection and storage system	• The online data collection and monitoring system developed	• -The capacity to use the online PMEL by project PIs and support staff was enhanced through training • -The online system was used to gather 2019 information on icipe primary and secondary reach
Assessing the impact of upscaling and institutionalizing of fruit fly IPM technology among smallholder fruit growers in East Africa (Phase V).	• Improved evidence of IPM technology use for fruit fly among smallholder fruit growers in East Africa.	• Baseline and follow-up data. • A working paper on the use of IPM on fruit flies.	• Baseline data collected and analyzed. • A baseline report produced.	• NA
NAME of Project: Combating the invasive tomato leafminer, *Tuta absoluta* through the Implementation of eco-friendly IPM approach on tomato in East Africa				
Objective 1: Knowledge on socioeconomic impact of the Tuta absoluta tomato growers' livelihood prior to the intervention enhanced				

Growers' current knowledge, attitudes and practices (KAP) related to tomato production and IPM technologies established and documented.	• At least 2000 farmers and other tomato value chain actors are aware of the knowledge, attitudes and practices (KAP) of farmers as regards tomato production and IPM technologies assessed.	• •Baseline survey datasets. • •At least one (1) report on "Farmers' Knowledge, attitudes and practices on tomato production and pest management in Kenya and Uganda" by end of Dec 2019.	• -One Msc student recruited to address the four objectives of these two projects. • -Baseline survey data collected in the project sites in Kenya, and data analysis initiated.	• Tuta absoluta is the major tomato infesting pests as reported by over 95% of the interviewed farmers in Kenya and Uganda. Use of synthetic chemicals is the main method (reported by 100% of the respondents) for management of the pest. Limited knowledge of IPM products, but positive willingness to pay for the alternative products other than use of pesticides.
Investigate the economic burden of T. absouluta in tomato production in the target project sites.	• •Stakeholders and partners made aware of the economic burden of tomato leaf miner, T. absoluta.	• •At least one (1) report produced before end of 2020. • •At least 1 peer reviewed paper by mid 2020.	• Ongoing.	• NA
Characterize tomato farming systems in the study areas and availability, access and utilization of different pest management practices including IPM products for combating the invasive tomato leaf miner, *T. absoluta*.	• Tomato production systems in the target sites documented and shared with stakeholders/tomato supply chain actors.	• •At least one (1) report produced before end of 2020.	• Ongoing.	• NA
Potential adoption, implementation feasibility and future sustenance of T. absoluta management approaches determined.	• •Potential demand of the innovative T.absoluta management approaches determined and shared with stakeholders.	• At least one (1) report produced before end of 2020.. • At least 1 peer reviewed paper by mid-2020.	• Ongoing.	• NA
Conduct a strengths, weaknesses, opportunities, and threats (SWOT)	• •Tomato market value chain actors informed about the economic feasibility of	• At least one (1) report produced before end of 2021.	• One MSc student hired to address this objective of the project • -Proposal and draft survey tool developed	•

analysis of the business concept to establish viability and acceptability of the business plan proposal.	commercializing fungal based biopesticide.			
NAME of Project: Alien invasive fruit flies in Southern Africa: Implementation of a sustainable IPM program to combat their menaces				
Objective 1: Assess the socioeconomic and gender impact of the IPM interventions in the mango production and value chain				
Understand barriers and success factors for promoting, scaling up IPM technologies and increase women's and youth participation in the mango value chain.	• Stakeholders are aware of the barriers and opportunities for promoting fruit fly IPM technologies especially among women and youth mango farmers.	• Focus group discussion (FDG) dataset from at least 2 of the target countries • Household-level baseline survey datasets from at least 2 of the target countries • One PHD thesis • At least 1 report and manuscript with a gender focus.	• Household surveys completed in Zambia and Malawi. • FGD survey completed in Zimbabwe. • PhD candidate recruited in Malawi. • Preliminary descriptive statistics for Zambia.	• Invasive fruit flies is major mango infesting pest in all the target countries, that significantly affects yields and quality of the mango fruits, resulting to low returns from mango production. As a result small holder farmers have limited investment in management of the pest and mango crop in general despite its high market potential across the region.
Forecast the potential demand for the developed IPM technologies in the target project area.	• Market players and development partners have evidence on the expected demand for the fruit fly IPM technologies.	• At least 1 report and manuscript.	• On-going.	• NA
Assess the impact of IPM interventions on income, nutrition, human health and environment outcomes using gender disaggregated data.	• Stakeholders have evidence on the impact of using fruit fly IPM products as opposed to conventional methods.	• At least 1 report and manuscript.	• On-going.	• NA
Conduct cost-benefit analysis of the existing management practices and the	• Farmers, policy makers and development partners are aware of the costs and benefits of the existing fruit fly management practices and proposed IPM technologies.	• -At least 1 report and manuscript.	• On-going.	• NA

proposed IPM technologies.				
Assessing and promoting successful modalities to connect smallholders with value chains.	• Farmers, policy makers and development partners are aware of successful market linkages for smallholder farmers.	• -Market survey dataset. • -At least (1) report. • -At least (1) manuscript.	• On-going.	• NA
Analysis of women's empowerment in at least one target country.	• Policy makers and development partners are aware Women's Empowerment in Agriculture Index (pro- WEAI) among mango growers in one of the target project countries.	• At least 1 report and manuscript.	• PhD candidate recruited in Malawi. • Gender disaggregated data collected through household-level survey in Malawi.	• NA
NAME of Project: Improving food and nutritional security through integrated control of tsetse and tick-borne livestock diseases (ICTLD)				
Objective 1: Impact of integrated tsetse and tick control using novel eco-friendly technologies on the livelihood of smallholder farmers evaluated				
Livestock producers' perceptions on the impacts and management practices of trypanosomiasis and tick-borne diseases, and constraints and opportunities to scale up improved livestock health management technologies in the target areas assessed.	• Farmers perceptions and constraints to adoption of integrated tsetse and ticks management practices documented and shared with project partners and other livestock value chain actors.	• Dataset • A report by end of 2019	• One PhD candidate recruited to address the four objectives of this project in Kenya and Ethiopia. • Draft household and FDG survey tool developed.	• NA
Ex-ante demand of the integrated tsetse and tick control and management technologies in the target areas determined.	• Traders and development partners in the livestock value chains made aware of the potential demand of the integrated tsetse and ticks management practices.	• At least one (1) working paper by mid-2020.	• on-progress.	• NA

Cost-effectiveness of the integrated tsetse and tick control and management technologies estimated.	• Traders and development partners in the livestock value chains made aware of the potential demand of the integrated tsetse and ticks management practices.	• At least one (1) working paper by mid-2020.	• on-progress.	• NA
Economic and nutrition effects of integrated tsetse and tick control and management technologies with emphasis on women and their children determined.	• At least 3000 community members in tsetse and ticks prone areas are made aware of the economic and nutrition effects of integrated tsetse and tick control and management practices and results shared with project.	• At least one (1) working paper by end of 2020.	• on-progress.	• NA
NAME of Project: PROSAFE: Promoting smallholder access to fungal biopesticides through Public Private Partnerships in East Africa				
Objective 1: Farmers' Knowledge and Management Practices of Cereal, Legume and vegetable insect pests, and willingness to pay (WTP) to pay for biopesticides				
Farmers' knowledge and management practices of Cereal, Legume and vegetable insect pests, and willingness to pay (WTP) to pay for biopesticides determined.	• Project partners and stakeholders are made aware of the knowledge and management practices of cereal, legume and vegetable insect pests, and farmers' willingness to pay (WTP)..	• Survey dataset • At least one (1) research report produced by end of 2019.	• Manuscript submitted for peer review "Nyangau, Paul, Muriithi, Beatrice, Diiro, Gracious, Akutse, Komivi, Subramanian, Sevgan; Farmers' Knowledge and Management Practices of Cereal, Legume and Vegetable Insect Pests, and Willingness to pay for Biopesticides. Submitted to *International Journal of Pest Management.*	• Fall armyworm identified as the major maize infesting pests, mainly controlled using synthetic pesticides. Positive willingness to pay for biopesticides identified among the surveyed farmers.
NAME of Project: INSFEED2: Insect feed for poultry, fish and pig production in Sub-Saharan Africa- Phase 2 (Cultivate Africa's Future Phase 2 (CultiAF 2)				
Objective: Assess the cost-effectiveness and potential livelihood effects of insect based feed technologies through gender lens[4] along the value chain				
Existing supply chain models for key commodities in Kenya and the role of the youth, women and men in feed supply assessed.	• Enhanced information about the existing supply chain models for key commodities in Kenya.	• One report the existing supply chain models for key livestock feed in Kenya produced.	• One MSc student recruited to work on this activity. • Stakeholder workshop held with key actors in the insect feed value chain. • SWOT analysis and participatory value chain mapping conducted and results shared in stakeholder workshop report.	• SWOTs revealed (a) strong interest to use BSF as replacement to animal protein to increase quality and reduce the price of animal feed, (b) concerns about missing policies and lack of clarity on government regulations,

[4] In this project, the term gender lens implies the gender heterogenous impacts of the insect based technologies on men, women (female headed households and female with male headed households) and youth will be carried out by collecting sex disaggregated data.

			• Qualitative interviews implemented and case studies prepared for key players in the insect feed value chain.	and (c) high demand for an information exchange platform. • Participants were of the view that most nodes of the insect feed VC are accessible to women and some nodes are dominated by women.
Economic benefits of insect farming and insect-based feed for poultry, fish and pig production systems along the value chain determined	• Policy makers and partners use improved evidence and knowledge on impacts of economic benefits of insect farming and insect-based feed	• One paper 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 produced	• Four MSc students recruited to work on this activity. • A baseline survey was conducted in with animal farmers in Kiambu and Kisumu counties. • Data were cleaned/prepared for use and initial analyses conducted. • Baseline survey report completed. • An easy-to-use manual for setting up successful insect farming enterprises of different scales of operation is near completion. • In process is a journal paper on the correlates of women's empowerment using the baseline survey data and a mixed-methods approach.	• -Average levels of awareness of insect feed technologies among the Kiambu sample are 33% (women) and 57% (men). The media was the main source of information on insect farming. • Initial results show percent empowerment among women householders, wives in men-headed households, and men householders is 60%, 41%, and 56%, respectively. For most empowerment indicators, differences across groups are not statistically, except men farmers have higher self-efficacy than women farmers, and wives have lower work-life balance than others.
Long-term potential impact of insect-based feed technologies on food and nutrition security estimated.	• Enhanced knowledge policy makers and partners on long-term potential long-term impact of insect-based feed technologies on food and nutrition security	• One paper on the long-term potential impact of insect-based feed technologies on food and nutrition security in Kenya produced	• Paper accepted for publication in the journal of Cleaner production ‘’ Abro, Z., Kassie, M., Chrysantus, T. Dennis., B, and Diiro, G. Socio-economic and environmental implications of replacing conventional poultry feed with insect-based feed in Kenya Journal of Cleaner Production • This same paper was also presented at the International Conference of African Agricultural Economists in Abuja, Nigeria, and presented at ILRI Addis Ababa campus research community •	• Depending on adoption rates and whether the commercial or the entire poultry sector in Kenya adopts it, insect feeds may have the potential to generate a yearly income equivalent of US$16–159 million in the short-run and 69–687 million in the long run. This income gain could be translated into higher food security, lower poverty, higher employment and contributes to cleaner environment. • From the two presentations of Abro et al paper, we have learned that experts have strong interest to

				insect production and processing incorporate in their research and projects. This is a good opportunity for the icipe to promote insect production and processing for feed and food.
Economic viability of insect-based feed supply chain models to guide scaling up pathways evaluated and determined.	• Policy makers and partners devise scaling up strategies based on improved evidence and knowledge of economic viability of insect-based feed supply chain models in Kenya	• One report on economic viability of insect-based feed supply chain models in Kenya produced	• Interviews conducted and enterprise budgets prepared for 10 medium- and small-scale insect farmers covering four different business models: substrate led, cyclical, insect farmer led, and contract farming model.	• Production levels and profits are currently low, given these enterprises are very new. However, all interviewed farmers see huge potential and plan to scale up production quickly.

NAME of Project:: Strengthening "out-grower" models for commercial production of high-quality and sustainable Insect-based animal feed protein engaging smallholder farmers and other value chain actors in Kenya (SiPfeed)				
Objective: To generate evidence-based data to support scaling and adoption of insect-based protein feed enterprises				
Different out-grower based supply chain models linking insect production with feed manufacturing sector evaluated.	• Enhanced information of partners and stakeholders about the existing supply chain models for key commodities in Kenya.	• One report on mapping and feasibility of supply chain models.	• One MSc student recruited to work on this activity. • Stakeholder workshop held with key actors in the insect feed value chain. • SWOT analysis and participatory value chain mapping conducted and results shared in stakeholder workshop report. • Qualitative interviews implemented and case studies prepared for key players in the insect feed value chain.	• See lessons under INSFEED2.
Impact of insect farming and insect-based protein for feed on the livelihoods of farmers determined.	• Policy makers, development agents are more informed about the potential benefits of insect farming and formulation of insect-based feed.	• Working paper on optimal and economical feed ratios for poultry and fish production produced. • A case study on impact of insect farming and insect-feed for poultry and fish production systems on productivity, income and, dietary diversity produced.	• Four MSc students recruited to work on this activity. • A baseline survey was conducted in with animal farmers in Kiambu and Kisumu counties. • Data were cleaned/prepared for use and initial analyses conducted. • Baseline survey report completed. • An easy-to-use manual for setting up successful insect farming enterprises of	• See lessons under INSFEED2.

			different scales of operation is near completion.	
NAME of Project: Partnership for skills in Applied Sciences, Engineering and Technology (PASET) Regional Scholarship and Innovation Fund (RSIF)				
Objective: Increasing female participation in PhD and research program				
Co-organize and participate in a major conference with women scientists and those working to advance women in STEM in sub-Saharan Africa.	• Increase RSIF visibility and develop social networks among gender experts and women scientists in SSA.	• Conference organization and participation.	• Co-organized and participated in the GoFoWiSeR conference, Dakar, July 18-19, including holding focus group discussions with 10-15 key informants (women scientists and gender experts).	
Conduct a mixed-methods gender study to understand why women have low representation in STEM fields in sub-Saharan Africa.	• Enhanced knowledge of the main socio-cultural, economic, and institutional factors that explain low representation of women in STEM fields.	• Gender consultant hired. • Mixed-methods. datasets collected. • A report and journal manuscript prepared.	• Gender consultant hired. • Qualitative interviews conducted at four RSIF-host institutions. • Survey Monkey survey launched. • Extensive literature review. • Grant proposal submitted to IDRC.	• Preliminary findings suggest that limited funding, lack of role models/mentors limited family support, gender stereotypes, and sexual harassment are some key factors associated with low female representation among STEM PhDs.
Develop a gender strategy to enhance women's participation in STEM PhD programs and research at African Universities.	• RSIF and host institutions informed of practical strategies to enhance women's participation in RSIF PhD programs.	• Gender strategy document.	• Initial gender strategy prepared.	
Develop a program theory of change and evaluation framework	• An enhanced understanding of the project approach and how it will be evaluated for impact	• Evaluation Framework document.	• A draft Evaluation Framework prepared.	
NAME of Project: BioInnovate Africa Programme				
Objective: Project monitoring and evaluation system implemented				
Develop and implement baseline and follow-up surveys for Cohort I and Cohort II consortium projects	• Project effectiveness and impact captured and documented.	• Two surveys designed and implemented.	• Two online surveys were implemented and the results used to update the project M&E systems. • A monitoring and evaluation capacity building workshop was organized with all project PIs and their partners.	
NAME of Project: INSect-based agriBIZiness for sustainable food production in Kenya and Uganda (INSBIZ Project)"				
Objective: Review of the State of Research and Utilization of the Long-Horned Grasshopper *Ruspolia differens* in Africa: Past, Present and the Future				
Value chain mapping and analysis of R. differens - based food supply chains	• Value Chain of Edible insects (Nsenene) from harvesters, employees, traders in Uganda	• Dataset from various edible insect (Nsenense) value chain actors	• Designed survey tools based (on SCP models) for harvesters, traders, and employees. • Between December 15th 2019 and January 15th 2020) we collected survey data from harvesters (n=101),	• The market for Nsenene is unstructured with majority (59% of the interviewed traders) operating on roadside markets. The rest

using Uganda as a case study.	assessed and documented.	(harvesters to employees). • At least one report. • At least one peer reviewed manuscript.	Nsenene traders (n=93) and employees of harvesters (n=217). • Data analysis and writing in progress to generate a draft report for the Nsenene value chain in Uganda.	operated from seasonal and undesignated markets.

7.7 Capacity Building and Institutional Development Programme: Results Based Management (RBM) Rolling Framework Report

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
Objective or Specific Objective: Increase the number of high-quality researchers and middle level practitioners required to respond to arthropod-related research and development challenges in Africa by 2020.				
Between 2014 and 2020, 60 PhD and 150 MSc postgraduate students (33% women) from at least 18 African countries representing all sub-regions of SSA, are at icipe at various stages of postgraduate training in arthropod and related sciences.	• At least 95% of students complete postgraduate training (33% women), representing 18 African countries. • At least 75% of PhD students who complete their training each year during 2014–2020 are contributing to research, development and higher education in Africa, dealing with reducing poverty, improving food and nutritional security, improving human, animal and environmental health; and working 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, dealing with reducing poverty, improving food and nutritional security, improving human,	• 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 2014–2020. • 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* engaged in research, development and higher education in Africa. • Number of researchers 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* during 2014 and 2020. • Number of graduates with positions of leadership in public & private organisations/ enterprises in Africa.	• During 2019, there were 82 PhD fellows and 98 MSc fellows at various stages of their postgraduate training programme. • In 2019, 46% of all postgraduate fellows were women. • In 2019, 18 African countries were represented by postgraduate students at icipe (Ethiopia, Kenya, Uganda, Benin, Tanzania, Rwanda, Cameroon, Sudan, Ghana, Cote d'Ivoire, Nigeria, Burkina Faso, Zimbabwe, Zambia, South Africa, Senegal, Togo, DRC) • In 2019, 16 PhD students and 11 MSc completed training with icipe. Of the 16 PhD students, 8 (50%) are engaged in research, development or higher education in Africa; 3 (19%) are engaged in research outside Africa; records are not currently available for 5 (31%). Of the 11 MSc students, 10 (91%) are pursuing a career in R&D or higher education in Africa. • We do not have records of the number of new research and development activities/projects implemented and/or led by trained PhD level scientists who completed during the period 2014-2020. • Approx. 134 students who completed training at icipe since 1983 are in senior positions (e.g. Vice Chancellor; Director, Assistant Director; Department Head; Professor, Associate Professors, Principal or Senior Research Scientist, Senior Lecturer, etc.), contributing to R&D or Higher Education in Africa. None of the	• Although we implement on-going tracking of all alumni of the icipe postgraduate programs, tracking of MSc students is difficult, especially those that pursue careers outside of research and higher education. • A routine plan for monitoring trainees after training should be incorporated into training programs. • Follow up of alumni should include the number of research project they lead.

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
	animal and environmental health.		students who completed since 2014 are in senior positions.	
Dissemination of research results by postgraduate students through 400 publications of research results (including theses, book chapters, peer-reviewed papers, conference abstracts and proceedings, training brochures and manuals, policy documents, print and online media) in the period 2014-2020.	• 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 during training (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.	• In 2019, of the 140 peer-reviewed papers published by *icipe*, 76 (54%) were authored by postgraduate students, (68 (49%) as lead authors). • Citation metrics: Peer-reviewed publications by students in 2019 had an average 2.08 citations (range 0-28), and 353 downloads (range 0 to 9266) per publication. • 16 PhD and 11 MSc theses were completed in 2019. • In 2019, 32 postgraduate students participated in 20 international/ regional scientific meetings & conferences and 5 local scientific meetings & conferences.	• Postgraduate students make a significant contribution to the research and publication output of *icipe*. To gauge the relative strength of student publications, we should include comparative analysis of publications authored by icipe scientists.
Career development opportunities for at least 20 early career scientists (short-term visiting scientists and postdoctoral fellowships (PDFs)) implemented during the period 2014–2020.	• At least 75% of PDFs 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 2014–2020. • At least 50% of fellows attract competitive research grants during their tenure at *icipe.*	• Number of postdoctoral fellows and visiting scientists trained. • Number of grants applied for and received by PDFs each year. • Number of research publications in peer-reviewed journals. • Number of postdoctoral fellows trained contributing to research, development and higher education in Africa.	• 16 postdoctoral fellows were engaged in research at icipe in 2019. • 32 peer-reviewed articles were published by postdoctoral fellows in 2019 (4 as lead author). • In 2019, *icipe* postdoctoral fellows participated in 29 grant applications; 11 were awarded and signed, 6 approved - awaiting contract, 4 are under review and 8 were unsuccessful (i.e. at least 59% success rate). • Of the 19 Postdocs recruited since 2014, 10 are still postdocs at icipe, 2 are now scientists with icipe, 4 are with national R&D systems, and 1 is deceased.	
Researchers, mid-level practitioners and extension workers (200) from 30 national	• At least 50% of trained middle-level practitioners	• Number of training courses. • Number of trainees.	• 44 training courses.	

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
systems in Africa trained in non-degree professional development courses during the period to 2014 - 2020.	applying their knowledge and expertise in Africa each year during the period 2014–2020.	• Number of new technologies produced and adopted.	• 1131 researchers, mid-level practitioners and extension workers trained from 15 countries in Africa. • New technologies produced and adopted: 10 (push-pull; biopesticides icipe 78 & 7; parasitoid biological control; pheromone traps; FAMEWS mobile app for monitoring and early detection of Fall Armyworm; protein bait; male annihilation; fruit fly traps and lures).	
Undergraduate interns (100) trained during the period 2014- 2020.	• At least 50% of trained undergraduate interns progressing to research and development careers each year during the period 2014–2020.	• Number of interns trained. • Number of internship reports.	• 80 interns were trained in 2019. Average duration of an internship was 3.3 months. • Tracking was completed for 74 former interns from 2016-2019. 18% are completing their BSc degrees, 36% are pursuing MSc and PhD degrees, 5% are completing an internship with another R&D organisation; and 18% have research assistant or consultancy positions with icipe.	• The number of interns in R&D has increased dramatically from 28 in 2017 to 80 in 2019. Because internships have become a significant component of capacity building at icipe, the program is now being restructured as a more formal capacity building program of *icipe*.
Research and training capacities in insect and related sciences strengthened at national and regional research and higher education institutions through the development of partnerships.	• At least 2 new research or training activities developed with partners each year during the period 2014–2020.	• Signed MoUs and collaborative agreements. • Number of exchange visits by network partners. • Number of network partners. • Number of research projects started. • Number of new training programmes in national systems.	• MoUs developed with KALRO, Makerere University, KEPHIS, TARI-Selian, TARI-MARI, Amhara Regional State Bureau of Agriculture for CAP-Africa (Combatting Arthropod Pests for Better Health, Food and Climate Resilience) capacity building. • New training programme started with Egerton University, Kenya (8 MSc and PhD students trained at icipe). • MoU pending with Jaramogi Oginga Odinga University of Science and Technology, Kenya, JOOUST for training of postgraduate students. • MoU with United States University in Africa, Kenya signed for capacity building and joint research projects.	

7.8 BioInnovate Africa Programme: Results Based Management (RBM) Rolling Framework Report

Outputs	*Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
Specific Objective 1: Generate biosciences innovations that address the needs of smallholder farmers and agro-processors in the region				
Bioscience knowledge that address the needs of smallholder farmers and agro-processors developed.	• 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 ideas emerging from the project. • Number of patents acquired at different levels of processing i.e. applied for, awarded, gazette.	1. 10 manuscripts and 2 scientific paper publications have been developed by supported project teams as follows: a. 5 manuscripts on Refractance Window Drying technology (RWD) b. 5 manuscripts on post-harvest water treatment, microencapsulation of ordour blends, novel enzymes, sorghum and millet value added products. c. 2 scientific papers published by icipe partners on biopesticide. 2. Four (4) product registrations are at various stages: a. One (1) patent was acquired for a bioalkanol gel fuel in Kenya. b. 2 trademark certificates were acquired for a fertilizer brand “HAKIKA” and mushroom brand “OKOA mushroom” both in Tanzania. c. A Plant Breeder’s Rights Certificate was acquired for Maseno EH14 maize variety in Kenya. d. Patent registration was initiated in Kenya for a biopesticide product ICIPE7 (Detain®) against fall armyworm. 3. 6 (six) new ideas emerged from supported projects: a. A dual refractance window drier (RWD) that uses both electricity and biomass for drying fruits was fabricated and is being tested. b. Anthocyanins and other antioxidants found in sweet potatoes, particularly purple fleshed varieties, may protect against certain cancers. Purple fleshed sweet potatoes may be good as	a. Innovation activities are inherently iterative. Therefore, flexibility is required during implementation of innovation projects. b. Continuous learning remains a vital aspect of implementing innovation projects. c. Continuous follow-up (virtual and physical) and support visits to project teams is necessary to align expectations of all partners.

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
			ingredients in dairy products such as smoothies. c. Complementary application of inorganic fertilizer and 'Hakika' brand of organic fertilizer (an innovative biobased product) gives excellent performance in plant growth and biomass/grain yield as compared to the sole application of either of them. The supported team is conducting selected farmer demonstrations in Tanzania and Uganda. d. Cricket diets with BSF (Black Soldier Fly) as a protein source leads to growth in a similar way as diets with fish meal as an ingredient. BSF feed will be availed to cricket farmers as an alternative protein source. In addition, diets with high protein and salt satiation significantly reduce cannibalism among long-horn grasshoppers. e. Agro bio-waste obtained from the bioconversion process may be used to substitute feed additives for fish, poultry and animal feed. This is being experimented by a supported team in Uganda. f. Fresh and dry catnip plants contain similar amounts of essential oil and the quality of the active ingredient is well preserved. Product development using dry catnip plants will be explored by the supported team. 4. 12 Women scientists completed their fellowship program at various partner institutions. 5. 13 fellowships were awarded to a 2^{nd} cohort of women scientists to participate in innovation projects at partner institutions.	

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
			6. Four (4) capacity building workshops on financial management, business incubation, Bio-Business acceleration and innovation ecosystems were organized for project teams of BioInnovate Africa. 7. Five (5) projects were selected to receive Innovation Challenge Awards to facilitate their engagement with potential investors.	
Innovative value-added goods address the needs of smallholder farmers and agro-processors.	• 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 products at different levels of development (proof of concept, lab/field validated product, validated market/customer segments, validated business model, product launch).	1. 15 value-added innovative products are at different levels of development: **i. Validated market/customer segments** a. 146 tons of 'Hakika' granulated organic fertilizer was produced, of which, 100 tons was sold to farmers. b. Approx. 1 metric ton of sorghum enriched instant porridge flours and snacks were produced and sold in Ethiopia, Tanzania and Uganda. c. Sales revenue were generated from selling aroma honey toffees to a wide range of customers in Uganda. d. Over 200 litres of bioalkanol gel fuel were minimally produced and test-sold to selected household customers in rural and peri-urban areas of Western Kenya. e. A licensing arrangement to commercialize striga resistant maize through seed companies. f. Insect-based feed from black soldier fly larvae was tested with poultry feed millers in Tanzania. g. Sales revenue were generated from nutrient-rich substrate blocks for mushroom production in Tanzania. **ii. Market-testing**	

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
			a. Mass production of three species of crickets (Scapsipedus icipe, Gryllus bimaculatus and Modicogryllus conspersus) was adopted by private sector partners in Kenya and Uganda. Assorted cricket-enriched cookies and flours were introduced for test-selling in 15 supermarkets in Uganda. b. A Chapati Delight business utilizing an average of 200kg of orange-fleshed sweet potato puree (OFSP) per week was launched for market testing Kenya. Also, a total of 55kg of OFSP baked rolls and sliders were produced in Rwanda for testing purposes. **iii. Lab/field validation** a. Field efficacy trial of ICIPE 78 biopesticide against Fall Army Worm was conducted. b. On-farm demonstration plots were established for striga-resistant finger millet varieties (NAROMIL 1-5 and Seremi 2) in Uganda. c. On-station trials using black soldier fly larvae-based feeds on Nile Tilapia Fry are being investigated from Fry to Fingerling stage in Tanzania. d. Protocols for the efficacy trials of catnip-based mosquito repellent products were approved by the Ethics Committee in Burundi. e. Prototypes of Novel Repellent Blends and Novel Attractant Blends were tested and found to be effective against G. m. submorsitans in Uganda and Tanzania. Sachets of optimal microns (pore sizes) for delivery of the blends were produced for testing purposes for tsetse and trypanosomiasis control. f. Prototypes of sweet sorghum syrup were minimally produced and tested as	

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
			ingredients in food consumption in Ethiopia, Kenya and Uganda.	
Innovative value-added services that addresses the needs of smallholder farmers and agro-processors.	• Enhanced capacity of Eastern African universities, research organizations to translate modern biosciences into innovations targeting smallholder farmers and agro-process enterprises in the region.	• Number of bioscience services at different levels of development (undergoing value addition, ready for market, market tested).	1. Two (2) bioscience services are ready for the market namely: a. An integrated wastewater treatment system has begun receiving customer orders (contracts) to establish wastewater treatment facilities in Arusha, Zanzibar and Moshi worth over USD 25,000. b. A mobile application (Viazi Vitamu) that links farmers in the sweet potato seed system is operational on Google App store. Over 30 farmers are registered on the App accessing market-related information and plant inspection services in Uganda. 2. Four (4) bioscience services are being market-tested: a. Vermicomposting methods to process coffee waste at commercial coffee estates to produce nutrient-rich compost and other byproducts for feed. b. Refractance Window Drying (RWD) for selected fruits and vegetables in Uganda. Four (4) RWDs were locally fabricated and installed in Uganda. c. Minimal quantities of processed leather from cow, goat and sheep skins were produced at small scale from enzymes of bacterial isolates for market-testing purposes. d. A 1,670-litre miniature hot water post-harvest treatment facility for fruits and vegetables is operational at *icipe* for both laboratory and market-testing purposes. Also, a 1,000-litre hot water treatment facility is installed at NARLI in Uganda for laboratory experiments.	

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
Bio-based business models that increase access of smallholder farmers, agro-processors and owners of agribusinesses to bioscience innovations.	• Increased linkages between research institutions and the private sector (agribusiness firms).	• Number of validated bio-based business models.	9 business models were validated: a. An integrated wastewater treatment system for managing waste from agroprocessing industries, municipal waste, tanneries and flower farms has been validated in Tanzania. b. High-quality aroma toffees made from honey for upper middle-income earners in Uganda. c. Value added sorghum instant flours, complimentary foods and cereals for a wide range of customer segments in Ethiopia, Tanzania and Uganda. d. Striga-resistant maize varieties promoted through seed companies in Kenya. e. ICTs integrated in sweet potato seed systems using a mobile application and artificial intelligence to diagnose diseases. f. Granulated nitrogen biofortified fertilizer 'Hakika' for small-to-large scale farmers in Tanzania and Uganda. g. Nutrient-rich substrate blocks using a one-stop center approach for mushroom farmers in Tanzania. h. Bioalkanol gel fuel for peri urban and rural households in Western Kenya. i. Black soldier fly larvae as alternative source of protein for chicken and fish feed.	
Spin-off companies developed and supported	Increased linkages between research institutions and the private sector (agribusiness firms)	Number of company registration certificates	Four (4) company registration certificates were acquired for the following spin-off enterprises: 1. BioCon Africa Limited in Tanzania 2. BioCon Uganda Limited. 3. Ecogel Enterprise Ltd in Kenya. 4. OKOA Mushroom Supplies Enterprises Limited in Tanzania.	
Networks and partnerships developed	• Increased linkages between research	• Increased linkages between research institutions and the	1. Three (3) Memoranda of Understanding (MoUs) were formalized between:	

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
	institutions and the private sector (agribusiness firms).	private sector (agribusiness firms).	a. TIRDO (Tanzania Industrial Research and Development Organization) and OKOA Mushroom Supplies Enterprises Ltd. b. TIRDO and SUGECO (Sokoine University Graduates Entrepreneurs Cooperative) c. Between Debre Berhan University and BioChain Enterprise. 2. A licensing agreement between Maseno University Seed Unit and Agri Seed Co was formalized. 3. A Non-disclosure collaboration agreement between Karire Products in Burundi and *icipe* 4. A Partnership agreement between Maseno University Seed Unit and Qualibasic Seed company was initiated.	
Relevant policy options to support scientists in their effort to promote bioscience innovations for smallholder farmers and agro processors evaluated.	• Improved prioritization and coordination of policy responses to promoting bioscience innovations.	a. Number of existing strategies/policies put by government that support and promote biosciences innovations. b. Number of existing regulations put by government that support and promote biosciences innovations.	**Progress in developing strategies/policies that support bioscience innovations:** 1. A draft version 1.3 regional bioeconomy strategy developed by the supported project team is being reviewed by national working groups and the drafting committee in each of the six BioInnovate countries including South Sudan. 2. Two (2) high-level bioscience policy seminars were held in Burundi and Uganda in collaboration with University of Burundi and chaired by Burundi's Minister of Higher Education and Scientific Research and in collaboration with Uganda's ministry of Science, Technology and Innovation in Kampala.	

Outputs	Outcomes	Performance Indicator	2019 Progress in Achieving Outcomes	2019 Lessons Learned
			Progress in developing regulations that support and promote bioscience innovations: 1. The Kenya Bureau of Standards, in collaboration with International Potato Center (CIP), released the sweet potato puree and bread standards to facilitate trade, safe and quality of OFSP puree products in Kenya. 2. A draft standard for Uganda with specifications on edible insects is in final stages of development in collaboration with local and international authorities.	
Bio-Innovate as an independent legally registered non-for-profit entity “Eastern Africa regional network for bioscience innovations (EARNBIN)”.	• Improved prioritization and coordination of policy responses to promoting bioscience innovations.	• Bio Innovate legally registered as an independent not-for-profit network “Eastern Africa regional network for bioscience innovations (EARNBIN)".	1. A draft version 1.0 concept note on the third phase of BioInnovate Africa programme is in place. 2. The Programme Advisory Committee (PAC) held its 5th and 6th meeting. 3. An online grants system is operational and is upgraded to incorporate progress reporting by project teams. 4. The BioInnovate Africa website has been upgraded with more features and a better outlook.	

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

Outputs	*Expected Outcomes*	*Performance Indicator*	*2019 Progress in Achieving Outcomes*	*2019 Lessons Learned*
Objective or Specific Objective Overall Objective: To strengthen the institutional capacity for quality and sustainable doctoral training, research and innovation in transformative technologies in sub-Saharan Africa (SSA) Specific objective 1) To develop the capacity for growth and management of a scholarship, research and innovation fund Specific objective 2) To establish PhD scholarships, research grants and innovation grants for Applied Sciences, Engineering and Technology (ASET)				
Progress toward achieving objective or specific-objective observed: The Regional Scholarship and Innovation Fund (RSIF), the flagship program of the Partnership for skills in Applied Sciences, Engineering and Technology (PASET) 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). During 2019, significant progress was made on all component areas of the program: viz, Component 1: Capacity Development for Operation of the Scholarship, Research and Innovation Fund; and Component 2: PhD Scholarships, research grants and innovation grants; as detailed below:				
Endowment Fund established with contributions from SSA governments, private sector, donors.	• Growth in endowment fund for sustained financing of scientific and technical talent development in Africa.	• Permanent fund established by end 2020.	• Firm contracted to undertake the feasibility study for establishing an RSIF endowment fund to work in tandem with its existing general fund; and inception report approved.	• Important to position the Fund as the first Pan-African regional science fund with a unique architecture designed for regional impact, multiple partners, flexibility of contributions with *icipe* ensuring common grant allocation rules and professional implementation. The Fund should be located in Africa.
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.	• PhD administration unit established by 2019 • Research and Innovation grants administration unit established by 2019.	• The unit is fully operational and staffed • Project operational manual developed and approved by PASET EB.	• *icipe's* existing capacity, experience and management processes allowed the smooth set up and operationalization of the unit and *icipe* was able to attract highly qualified staff.
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	• At least 10 agreements signed with RSIF African Host Universities by 2023	• *icipe* signed agreements with 10 RSIF African Host Universities[5] in October 2019.	• Universities require support to strengthen supervision and mentorship for PhD students.

[5] Nelson Mandela African Institution of Science and Technology (Tanzania), African University of Science and Technology (Nigeria), Sokoine University of Agriculture (Tanzania), University of Ghana (Ghana), University of Port Harcourt (Nigeria), University of Nairobi (Kenya), University of Gaston Bérger (Senegal), University of Rwanda (Rwanda), Bayero University (Nigeria) and University Félix Houphouët-Boigny (Côte d`Ivoire).

	African Host Universities.	• At least 10 RSIF African Host Universities with an online application system in place by 2023. • At least 10 African Host Universities start international accreditation process for the PhD programmes by 2023. • 10 cross-cutting training courses/workshops held for RSIF scholars and researchers by 2023.	• Eight (8) African Host Universities have online application system in place and RSIF has a centralized system. • 4 cross-cutting training course/workshops were held by end 2019 in Research Communications; Digital Storytelling; Research Ethics, Information Literacy. • Seven (7) new international partner agreements were signed in 2019.	• Strategic use of technology needs to be integrated as the number of countries and scholars are rapidly increasing.
Capacity for the operation and management of innovation grants built.	• Capacity for the operation and management of innovation grants built. • Improved research and innovation capacity in ASET including transformative technologies in SSA. • More industry - university partnerships . • More patents filed. • More enterprises developed. • More employment opportunities created	• Innovation grants unit established by 2020. • 10 firms co-finance innovation grants by 2023 . • 6 innovation grants awarded to RSIF African Host Universities by 2023. • 5 innovation grants awarded to faculty of RSIF African Host Universities by 2023.	• Innovation grant unit was established and staffed. • The first calls for innovation grants was published as planned and is on track for evaluation and award from 2020. • Grant manuals to guide operations of the unit developed and approved.	• Innovation systems at national and university level have limited functionality and need to be guided on how to improve.
More female participants in RSIF	• Increased stock of female (and male) scientists in the ASET.	• At least 82 (26 female and 56 male) RSIF scholars graduate from PhD programs by 2023.	• *icipe* took on responsibility for managing 15 existing Cohort 1 scholars (12 male and 3 female).	• Only 20% of the 1752 applicants to Cohort 2 Call for Scholarships were female. Need for greater intentional

			• The call for Cohort 2 of PhD scholarships was launched, and 64 students awarded based on competitive evaluation completed. • Third call to be issued in 2020 for further over 100 students.	effort to target females and faculty.
Increase in quality of research publications on ASET in Africa.	• Increase in productivity.	• At least 20,000 scientific and technological journals and databases that can be accessed by RSIF scholars and 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 African Host Universities and international partners for PhD training and research collaboration by 2023. • At least 120 student/staff that take cross-cutting courses, entrepreneurship and / or research commercialization courses supported by the project by 2023. • At least 10 grants awarded to faculty of RSIF African Host institutions Universities by 2023. • At least 16 research grants awarded to RSIF scholars by 2023.	• RSIF African Host Universities and RSIF PhD students and researchers have access to 20,000 scientific journals in ASET fields through Research4Life and other publication outlets. • Discussions held on creation of training and research collaboration networks to strengthen university capacity. • 15 students took cross-cutting courses in 2019.	• Following a scoping study commissioned by *icipe,* some gaps in RSIF African Host University capacities were identified, including around quality supervision and accreditation. In response a capacity building strategy is under development and PASET governance are encouraging *icipe* to share from its expertise and strongly integrate capacity development in all the RSIF funding windows. • After analyzing the applications to the first round of calls *icipe* decided to host a workshop to strengthen grant writing skills for RSIF Host University faculty.

SECTION 4: LIST OF JOURNAL ARTICLES (PEER REVIEWED) (JANUARY – DECEMBER 2019)

2019 (143)
KEY:
NAMES IN ITALICS: *icipe* researchers
GOLD OA – Gold Open Access
GREEN OA – Green Open Access
S - Subscription based
IF – Impact Factor

1. Abdalla A., Cen H., *Abdel-Rahman E.*, Wan L. and He Y. (2019) Color calibration of proximal sensing RGB images of oilseed rape canopy via deep Learning combined with K-Means algorithm. *Remote Sensing* 11, 3001. https://doi.org/3010.3390/rs11243001. IF 4.118; GOLD OA
2. *Agha S.B.*, *Tchouassi D.P.*, Turell M.J., Bastos A.D.S. and *Sang R.* (2019) Entomological assessment of dengue virus transmission risk in three urban areas of Kenya. *PLOS Neglected Tropical Diseases* 13, e0007686. https://doi.org/0007610.0001371/journal.pntd.0007686. IF 4.487; GOLD OA
3. *Aidoo O.F.*, *Tanga C. M.*, *Khamis F.M.*, *Rasowo B.A.*, *Mohamed S.A.*, Badii B.K., *Salifu D.*, Sétamou M., *Ekesi S.* and Borgemeister C. (2019) Host suitability and feeding preference of the African citrus triozid *Trioza erytreae* Del Guercio (Hemiptera: Triozidae), natural vector of "Candidatus Liberibacter *africanus*". *Journal of Applied Entomology* 143, 262–270. doi: 210.1111/jen.12581. IF 1.827 GREEN OA
4. *Aidoo O.F.*, *Tanga C.*, *Mohamed S.*, *Rasowo B.A.*, *Khamis F.*, Rwomushana I., *Kimani J.*, *Agyakwa A.K.*, *Salifu D.*, Mamoudou S., *Ekesi S.* and Borgemeister C. (2019) Distribution, degree of damage and risk of spread of *Trioza erytreae* (Hemiptera: Triozidae) in Kenya. *Journal of Applied Entomology* 143, 822–833. https://doi.org/810.1111/jen.12668. IF 1.827; S
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6. Aigbedion-Atalor P.O., Hill M.P., Zalucki M. P., Obala F., Idriss G.E., *Midingoyi S.K.*, Chidege M., *Ekesi S.* and *Mohamed S.A.* (2019) The South America tomato leafminer, *Tuta absoluta* (Lepidoptera: Gelechiidae), spreads its wings in eastern Africa: Distribution and socioeconomic impacts. *Journal of Economic Entomology*, https://doi.org/10.1093/jee/toz1220. IF 1.779; S
7. *Ajene I.J.*, *Khamis F.*, *Mohamed S.*, *Rasowo B.*, *Ombura F.L.*, Pietersen G., van Asch B. and *Ekesi S.* (2019) First report of field population of *Trioza erytreae* carrying the huanglongbing-associated pathogen, '*Candidatus* Liberibacter asiaticus', in Ethiopia. *Plant Disease Notes* 103, 1766. https://apsjournals.apsnet.org/doi/1710.1094/PDIS-1701-1719-0238-PDN. IF 3.583; GOLD OA
8. *Akutse K. S.*, *Kimemia J.W.*, *Ekesi S.*, *Khamis F.M.*, *Ombura O.l.* and *Subramanian S.* (2019) Ovicidal effects of entomopathogenic fungal isolates on the invasive fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Journal of Applied Entomology* 143, 626–634. https://doi.org/610.1111/jen.12634. IF 1.827; S
9. *Ambele F.C.*, Bisseleua H.D.B., *Akutse K. S.*, Babalola O.O., Humbert P., Patel A., Vidal S., Djuideu C. T. L. and *Ekesi S.* (2019) Testing a co-formulation of CO2-releasing material with an entomopathogenic fungus for the management of subterranean termite pests. *Mycological Progress* 18, 1201–1211. https://doi.org/1210.1007/s11557-11019-01517-y. IF 2.0; S
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11. *Asale A.*, *Kussa D.*, Girma M., *Mbogo C.* and *Mutero C.M.* (2019) Community based integrated vector management for malaria control: Lessons from three years' experience (2016–2018) in Botor-Tolay district, southwestern Ethiopia. *BMC Public Health* 19, 1318. doi:1310.1186/s12889-12019-17606-12883. IF 2.567; GOLD OA
12. Attardo G.M., Abd-Alla A.M.M., Acosta-Serrano A., Allen J.E., Bateta R., Benoit J.B., Bourtzis K., Caers J., Caljon G., Christensen M.B., Farrow D.W., Friedrich M., Hua-Van A., Jennings E.C., Larkin D.M., Lawson D., Lehane M.J., Lenis V.P., Lowy-Gallego E., *Macharia R.W.*, Malacrida A.R., Marco H.G., *Masiga D.*, Maslen G.L., Matetovici I., Meisel R.P., Meki I., Michalkova V., Miller W.J., Minx P., Mireji P. O., Ometto L., Parker A.G., Rio R., Rose C., Rosendale A.J., Rota-Stabelli O., Savini G., Schoofs L., Scolari F., Swain M.T., Takáč P., Tomlinson C., Tsiamis G., Van Den Abbeele J., Vigneron A., Wang J., Warren W.C., Waterhouse R.M., Weirauch M.T., Weiss B.L., Wilson R.K., Zhao X. and Aksoy S. (2019) Comparative genomic analysis of six *Glossina* genomes, vectors of African trypanosomes. *Genome Biology* 20, 187. https://doi.org/110.1186/s13059-13019-11768-13052. IF 14.028; GOLD OA

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14. Baguma J., Otema M., Ddamulira G., Naluyimba R. and *Egonyu J. P.* (2019) Distribution and incidence of the oil palm weevil *Rhynchophorus phoenicis* (Fabricius, 1801) (Coleoptera: Curculionidae) in selected agro-ecological zones of Uganda. *African Entomology* 27, 477–487. https://doi.org/410.4001/4003.4027.0477. IF 0.536; S
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