2018 *icipe* CORE ANNUAL REPORT

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

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icipe

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List of Acronyms

ADFI	Average Daily Feed Intake
ADG	Average Daily Weight Gain
ADFI	Average Daily Feed Intake
ARPPIS	African Regional Postgraduate Programme
BAP	BioInnovate Africa Programme
Bti	*Bacillus thuringiensis israelensis*
CABI	Centre for Agriculture and Biosciences International
CAP-Africa	Combating Arthropod Pests for Better Health, Food and Resilience to Climate Change
CBFAMFEW	Community-based Fall armyworm monitoring, forecasting, early warning and management system
CBID	Capacity Building and Institutional Development Programme
CCBSFLM	Black Soldier Fly Larvae Meal
CCD	Colony Collapse Disorder
CEO	Chief Executive Officer
CESPS	Community Extension Service Providers
DFID	Department for International Development
DNA	Deoxyribonucleic acid
DRIP	Dissertation Research Internship Programme
ECoMoPP	The East Africa collaboration on Mosquito Push-Pull ERC Energy Regulatory Commission
FAMEWS	Fall Armyworm Monitoring and Early Warning System
FAO	Food and Agriculture Organisation of the United Nations
FAW	Fall Armyworm
FCE	Feed Conversion Efficiency
FM	Fishmeal
GC	Governing Council
icipe	International Centre of Insect Physiology and Ecology
IPER	*icipe* Periodic External Review
NACOSTI	National Commission for Science, Technology and Innovation
PASET	Partnership for Skills in Applied Sciences, Engineering and Technology
PCPB	Pest Control Products Board
PPT	push–pull technology
R&D	Research and development
RBM	Results Based Management
RSIF	Regional Scholarship and Innovation Fund
SSIAU	Social Science and Impact Assessment Unit
UNEP	United Nations Environment Programme
KPIs	Key Performance Indicators
ToTs	Training of Trainers
MoU	Memorandum of Understanding
YESH	Young Entrepreneurs in Silk and Honey
KENTTEC	Kenya Tsetse and Trypanosomiasis Eradication Council

EXECUTIVE SUMMARY

icipe 2018 Results Based Management Report

This report highlights achievements and significant progress made on several fronts by *icipe* during the period January – December 2018. The Centre's Research and Development (R&D) Themes, Units, Programmes and Country Offices continue to develop innovative solutions to tackle challenges in agriculture, health and the environment sectors for a better and healthier Africa.

The Centre successfully completed the *icipe* Periodic External Review (IPER: 2013-2017) which started in the early part of March 2018.

The IPER Review Team of three international experts highlighted the Centre's unrelenting commitment to science and innovation-led development for sustainable, socio-economic transformation in Africa. The team indicated that the process of IPER has been fair, transparent and impartial. The team concluded that *icipe* is a well-managed and highly productive research Centre and their findings are oriented to significantly improve and strategically position the Center in the medium-term. The report highlighted the achievements and successes of the Centre, identified the many strengths but also specified areas that require strengthening. *icipe* management responded and, in most cases, has already taken concrete steps to address the Review Team's Recommendations.

The target malaria project team from the Human Health Theme applied molecular approaches to analyse the bionomic traits (species composition, *Plasmodium* infectivity, blood meal sources) and genetic structure of wild-caught *An. funestus senso lato* (s.l.) specimens from multiple major malaria endemic areas in Kenya. The analysis showed that *Anopheles funestus* s.s. was the main vector species in the Funestus group. This study underscored the importance of active surveillance through application of molecular approaches to unravel novel parasite-vector associations and their genetic structure.

The Animal Health Theme successfully obtained approval for registration of the tsetse repellent technology from the Kenya Pest Control Products Board (PCPB), paving the way for commercial production and distribution. The award of the certificate in May 2018 has enabled *icipe* to proceed with a commercialization plan that includes progressing towards a licensing agreement with a private sector company. Two new prototype dispensers will be evaluated as part of the scaling up, a canvas- based collar and one developed from plastic material. Registration and commercialization will allow for expansion beyond the pilot area of Shimba Hills National Park and also scaling up beyond Kenya. Field efficacy trials for registration of *M. anisopliae* isolate ICIPE 7, commercially known as Tickoff® were conducted in partnership with Real IPM Ltd., Kenya – in parallel with similar trials conducted by the Livestock Department of the Ministry of Agriculture, Kenya. Three eminent scientists from Europe and North America reviewed the R&D achievements of the Animal Health Theme. The reviewers concluded that the combination of high quality basic science with clear translation of results is impressive and internationally competitive.

In the Plant Health Theme, the Push-pull group have identified two commercial cultivars of *Brachiaria* forage grasses that are not only resistant to red spider mites (a problem on the current Push-pull companion *Brachiaria* hybrid) but also better adapted to drought stress. Surveys were conducted in western Kenya and maize grain samples were collected from push-pull and non-push-pull plots to determine the impact of cropping systems on occurrence of mycotoxigenic fungi and associated mycotoxins. This work demonstrated effective control of maize ear rots, aflatoxins and fumonisin with push-pull cropping system. A recent observation has clearly demonstrated that the push- pull technology effectively controls the Fall armyworm (FAW). Fungal-based entomopathogens have also been found to be highly potent to the pest in addition to the discovery of several parasitoids that have formed new associations with the pest, including a newly discovered braconid, *Cotesia icipe*. *icipe* and the Centre for Agriculture and Biosciences International (CABI) contributed extensively to the development of a FAW monitoring and management manual, which has been translated into French for partners in Burundi.

The bee health team of the Environmental Health Theme is making progress in studying the pollination behaviour of different stingless bee species during foraging on different horticultural crops in greenhouses. The team is comparing the pollination efficiency among different stingless bee species in setting yield and fruit/ seed quality in different horticultural crops. This knowledge will help in guiding farmers on which bee pollinator species to use in crop production. This work aims to promote stingless beekeeping as an additional farming activity contributing to supporting livelihoods among smallholder agriculture farmers in Africa through honey production and crop pollination. As part of the work on bioprospecting, "Uzimax", a plant-derived mosquito larvicidal product for vector control, is in the final stage of registration. The project on "Up-scaling sustainable commercial production of medicinal plants by community-based conservation groups in Kakamega forest in Kenya" has developed 16 toolkits on sustainable consumption and production of medicinal plants, health and safety; and distributed 3,108 copies of the toolkit of *Ocimum kilimandscharicum* as an empowerment tool for use by farmers. The Young Entrepreneurs in Silk and Honey (YESH) project enrolled 4,000 additional youth in apiculture areas and another 1,100 youth in sericulture areas.

Researchers from the Social Science and Impact Assessment Unit (SSIAU) used data from 711 cereal growing households in western Kenya to assess the impacts of women's empowerment in agriculture individually as well as in combination with push–pull technology (PPT) on women's and households' nutritional status. The team found that women's empowerment has a positive and significant effect on women and household dietary diversity scores. The impact is significantly higher for empowered women belonging to PPT-adopting households than their counterparts who have not adopted PPT. This work indicated that individual and household welfare could be enhanced to a greater degree by combining women empowerment with technology adoption than by treating the two elements as separate issues of development. Wide-scale dissemination of PPT in eight countries (Kenya, Uganda, Ethiopia,Tanzania, Malawi, Rwanda, Zambia and Zimbabwe), directly reached 25,284 smallholder farmers who adopted the technology, cumulatively bringing the total number of push-pull adopters to 207,058. In addition, approximately 5.1 million beneficiaries were indirectly reached through the efforts of partners and farmer to farmer disseminations as well as mass media. Surveys from the various countries demonstrated that the PPT is effective in controlling Fall armyworm (FAW) and represents the first documented evidence of a technology that can be immediately deployed for management of this invasive pest throughout Africa.

Through a competitive process*, icipe* was selected by the World Bank as the grantee agency and implementing entity for the project "Africa Regional Scholarship and Innovation Fund (RSIF) for Applied Sciences, Engineering and Technology a flagship project of the Partnership for Skills in Applied Sciences, Engineering and Technology (PASET).

icipe continues to play a major role in creating the next generation of researchers in insect and related sciences in Africa through postgraduate, postdoctoral and research internship programmes with a strong gender lens. Capacity Building and Institutional Development (CBID) Programme trained 82 PhD scholars including 48 (21 female) ARPPIS (African Regional Postgraduate Programme in Insect Science) PhD scholars, 34 (14 female) DRIP (Dissertation Research Internship Programme) PhD scholars and 56 (31 female) DRIP MSc scholars, 9 (2 female) Postdoctoral fellows, and 52 (33 female) Research Interns during the reporting period. Two ARPPIS PhD scholars, six DRIP PhD scholars and 14 DRIP MSc scholars defended their thesis or graduated. Alumni of the *icipe* postgraduate programmes are playing an important role in the multiplier effect of capacity building. A recent tracer study of 42 PhD scholars who completed in 2013-2018, showed 83% are engaged in R&D and higher education in Africa.

In 2018, *icipe* published 151 peer reviewed journal articles with fifty-six (56%) of the peer-reviewed papers published during the reporting period being first-authored or co-authored by postgraduate scholars or postdoctoral fellows. Plant Health Theme scientists contributed to three chapters in the first edition of a book on "*Fall Armyworm in Africa: A guide to integrated pest management*". A chapter entitled *"Legislation for the use of insects as food and feed in the South African context"* was published in the book on "Edible insects in Sustainable Food Systems". Since December 2017, the *International Journal of Tropical Insect Science* has been using the Aries Online Manuscript Submission and Peer Review system to further improve its impact factor.

SECTION 1: INTRODUCTION

1.1 *icipe* Brief Background

Established in 1970, the International Centre of Insect Physiology and Ecology (*icipe*) (www.icipe.org) is a pan-African, non-governmental and non-profit Centre of Excellence for research, development and capacity building in insect science and its application. It is headquartered in Nairobi, Kenya with 556 scientific and support staff. The Centre works on a 4-H (Health) paradigm, including plant, animal, human and environmental health, with arthropods as the common denominator to help alleviate poverty, and ensure food and nutritional security for smallholders in Africa. *icipe* focuses on green and sustainable pest control and is presently engaged in 40 African countries, and has thriving partnerships and excellent networks with many universities and research organisations in Europe and North America.

icipe is a founding member of the Association of International Research and Development Centers for Agriculture (AIRCA), a nine-member alliance that was established in 2012, which is focused on improving global food security by supporting smallholder agriculture within healthy, sustainable and climate-smart landscapes (www.airca.org) and is hosted at its Nairobi Campus. *icipe* is a designated Food and Agriculture Organisation of the United Nations **(FAO) Reference Centre** for vectors and vector-borne animal diseases, which include tsetse flies and animal trypanosomosis as well as arthropod-transmitted viral animal pathogens. Since 2010, *icipe* is a United Nations Environment Programme (UNEP) ***Stockholm Convention Regional Centre*** on Persistent Organic Pollutants (POPs). The Stockholm Convention is a United Nations international environmental treaty that aims to protect people, animals and the environment from chemicals.

In May 2017, *icipe* was officially designated as an **OIE Collaborating Centre for Bee Health in Africa** by OIE – World Organisation for Animal Health (the intergovernmental organisation responsible for improving animal health worldwide). This designation is significant as it formally recognises *icipe's* role as a hub for bee health R&D and expertise in Africa and globally. This recognition of *icipe* as an OIE Collaborating Centre for Bee Health in Africa will elevate its continent-wide basis and mandate and provide further confidence for stakeholders in Africa to collaborate with the Centre. *icipe* was granted a **National Commission for Science, Technology and Innovation (NACOSTI) Certificate of Registration**, jointly endorsed by the Cabinet Secretary, Ministry of Education, Science and Technology, and the Director General, NACOSTI, Kenya in March 2017. The certification signifies *icipe's* compliance with the Science, Technology and Innovation Act (No. 28 of 2013), which, in part, mandates NACOSTI to regulate and assure quality in the science, technology and innovation sector.

The Centre has outstanding research facilities including FAO accredited quarantine facilities as well as a Good Manufacturing Practices (GMP)-compliant enhanced Biosafety level 2/3 laboratory (the Martin Lüscher Emerging Infectious Diseases Laboratory), insectaries, and a state-of-the-art African Reference Laboratory for Bee Health. These facilities enable the Centre to address the increasing need for preparedness and response to emerging animal and human diseases in the region.

1.2 *icipe* Centre-wide Themes/Programmes

The following are the overall objectives of the 4-H (health) Themes and Capacity Building and Institutional Development (CBID) Programme.

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. Phase II of the BioInnovate Africa Programme began in November 2016 and will run until November 2021. While funding bio-based innovation projects remains the core activity for the programme, BioInnovate Africa's strategy also includes developing a knowledge-based bioeconomy in eastern Africa. This is built on the premise that collaboration at national and regional level, and between researchers and private sector partners, is the surest way to translate scientific outputs into usable, and commercially scalable products and technologies. 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 technology (ICTs) including big data and artificial intelligence; food security and agribusiness; climate change; energy including renewables; and minerals, mining and materials engineering. The PASET-RSIF Programme was approved by the World Bank in June 2018, became "effective" in September 2018 and will be implemented over a six-year period ending 30 June 2024. The programme financing is from World Bank International Development Association, Government of Korea and Individual country governments of Côte d'Ivoire, Ethiopia, Kenya, Rwanda, and Senegal. *icipe* was competitively selected as the Regional Coordination Unit (RCU) for the programme effective August 2018, with mandate to implement the RSIF Project on behalf of PASET.

1.3 Brief on *icipe's* Results Based Management Framework

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. Prior to the implementation of the RBM-LFA, *icipe* used the Medium-Term Plan as a reporting framework but like many other international organisations, it introduced RBM in early 2011 as its new strategic planning and management tool. 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.

The RBM-LFA is useful for *icipe* in promoting efficient management techniques. The systematic approach of gathering and assessing progress of results that is measured against key objectives is a cost-effective way

[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

to diagnose early weaknesses in implementation plans. Periodic and targeted information enables the GC and *icipe* Management to recognise activities that generate the highest pay-offs in terms of results, or those that require support to deliver key results that are aligned with strategic priorities. This approach enables the Centre to track and measure progress towards outputs and outcomes, and thus reach targeted decisions to improve performance on a progressive basis. Process monitoring is a critical part of the exercise to monitor whether portfolios are being implemented as intended, standards are being met, and resources are being used efficiently.

Each of *icipe's* core activity area has specific RBM framework. All projects activities go through a cycle of knowledge management and continuous learning. The Thematic Programmes and Capacity Building frameworks cover a cycle of planning, periodic performance assessment and organisational learning – all of which are supportive of knowledge creation and sharing. Learning from the R&D activities influences strategy development and programmatic and project design, and lessons learnt periodically feeds back into programme/project implementation. The learning component is also critical for identifying and managing risks while bearing in mind the expected results and resource levels. This has helped to increasingly expand the knowledge of each operation through learning, knowledge dissemination and feedback for decision making, project design and strategy development.

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.

In 2018, the Centre made great progress in achieving outcomes of its R&D activities as captured in the following reports from each of the Theme/Programme at *icipe*. During the reporting period of January – December 2018, *icipe* published a total of 151 peer reviewed journal articles and several other articles and publications of scientific value.

SECTION 2. 2018 Advances in Achieving Research and Development (R&D) Outputs and Outcomes

icipe contributes collectively to steadily increase its influential position as a scientific organisation working actively in more than half of all the countries on the African continent. *icipe*'s blend of R&D activities that span the spectrum of new discoveries in fundamental science to strategic applications that deliver practical outcomes have continued to impact its constituents. *icipe*'s main focus on 4-H paradigm is providing solutions for tackling challenges in health, food and nutritional security, and the environment.

Research activities of all health themes and programmes continue to match their focus on science with a parallel commitment to making a difference on the ground by employing diverse combinations of technology transfer models, partnerships, training and communication to encourage adoption and improve livelihoods.

A few examples in achieving the major R&D objectives in 2018 are highlighted below.

1 R&D Themes

1.1 Human Health Theme

1.1.1 *Malaria*

The East Africa collaboration on mosquito push-pull (ECoMoPP): The team is advancing its work on the proof of concept for odour-based push-pull systems to divert mosquitoes from biting people outdoors. This is a joint activity between *icipe* and the Ifakara Health Institute, Tanzania. The team has developed and optimized a push-pull product over the past 12 months under-semi-field conditions to push mosquitoes away from peri-domestic areas (spatial repellents) and to pull them towards odour-baited traps. Under experimental conditions a reduction of >50% of human biting was observed in the presence of the system. Consequently, a small-scale field trial has been initiated to test the application under field conditions in the rice irrigation scheme in Ahero, western Kenya.

Identification of novel oviposition attractants for malaria mosquitoes: The development of vector control and monitoring tools that target malaria mosquitoes outside houses and tools that are not insecticide-based have been prioritized by all major funding organizations and the World Health Organization (WHO) to close the currently existing control gap (i.e. exophilic and insecticide resistant populations). Targeting oviposition-site seeking mosquitoes by utilising odour cues would provide one of such tools. Olfactory cues released from grasses, specifically wetland grasses that have direct or indirect association with fungi might be used by gravid malaria mosquitoes in search for egg-laying sites. We are testing the relationships between swamp grasses, associated fungi and oviposition site selection of malaria vectors in the laboratory, semi-field and field conditions. Over the past 12 months extensive field work was implemented to identify and collect swamp grasses associated with aquatic habitats. Bioassays to test for attraction and oviposition are ongoing. This work contributes to the development of novel attract and kill strategies for malaria vector control.

Target malaria project: Effective intervention strategies against malaria towards elimination demands active entomological surveillance, to guide control interventions in the event of changing local conditions or discern cryptic species contributing to stealth transmission. The team applied molecular approaches to analyse the bionomic traits (species composition, *Plasmodium* infectivity, blood meal sources) and genetic structure of wild-caught *An. funestus senso lato* (s.l.) specimens from multiple major malaria endemic areas in Kenya. The analysis showed that *Anopheles funestus* s.s. was the main vector species in the Funestus group. It is noted that *An. longipalpis* C was also present and naturally infected with *Plasmodium falciparum*. These findings unraveled a previously unreported potential malaria vector in the Funestus group whose *COI* or ITS2 sequences did not match with reference sequences. This potential vector was found to be infected with the *Plasmodium* parasite, and it displayed high human feeding potential. *Anopheles funestus s.s.* was found to be subdivided into 3 unique genetic clusters in Kenya, based on microsatellite analysis, with genotypes mirroring the degree of *Plasmodium* infectivity and thus, malaria endemicity in Kenya. These findings underscore the importance of active surveillance through application of molecular approaches to unravel novel parasite-vector associations and their genetic structure.

Scent of disease - Use of volatile biomarkers for diagnosis of malaria infections in humans: Disease pathologies have long been known to influence the body odours of humans, knowledge which has been fundamental to the advancement of diagnostics for life threating diseases such as tuberculosis, lung cancer, among others. For malaria, studies on humans and in animal models have shown that infection by the malaria parasites induces changes in host odors that influence vector attraction, suggesting that such changes might yield robust biomarkers of infection status. The team in collaboration with researchers from The Swiss Federal Institute of Technology - ETH Zürich, Switzerland analysed skin volatiles from human populations with high rates of malaria infection in Kenya. The findings revealed: (i) effects of malaria infection on human volatile profiles and distinctness between symptomatic and asymptomatic infections; (ii) through application of models, identification of asymptomatic infections with 100% sensitivity, even in the case of low-level infections that are not detectable by microscopy, far exceeding the performance of currently available rapid diagnostic tests in this regard; and (iii) identity of a set of individual compounds as important predictors of infection status. Overall, these findings highlight the potential use of volatile biomarkers for malaria infection diagnosis as a non-invasive method under field conditions.

Plant-feeding association of Afrotropical disease vectors: Malaria vector surveillance requires improved trapping tools that are important in revealing adult population density and assessing success of malaria vector control measures towards elimination. This can be achieved by utilizing host derived odour-baited trapping systems. By combining constituents from both plant- and mammalian derived sources through detailed laboratory and field studies, the team has developed improved lures for surveillance of malaria vectors. Findings revealed a dose-dependent effect on trap catches while combining odorant blends from both sources with significantly improved trap catches at higher doses. Notably, a three-component lure comprising plant-derived odorants was found to improve captures of varied malaria vectors, albeit to differing efficacy among the species.

Mapping wetness potential (flooding sites) to guide malaria vector control: Wetness sites are a suitable habitat for mosquito vectors that transmit malaria. The team utilized time-series freely available satellite data sets to map the potential water collected areas and wetlands. The two maps (potential water collected areas and wetlands) were combined to generate an accurate flooding map in Busia County, Kenya. This timely and geo-referenced flooding map helps in understanding the malaria risk drivers and spatial variabilities of malaria propagation and outbreak. Also, flooding maps can guide the implementation of site-specific malaria preventive and control technologies.

1.1.2 *Arboviruses*

Yellow fever, dengue and other arboviruses: The project seeks to assess the risk for transmission of mosquito-borne viral diseases, primarily Yellow Fever (YF) and Dengue in selected parts of Kenya including three main cities, Mombasa, Nairobi and Kisumu and also along the borders, West Pokot and Turkana. Risk is being measured by: (1) Determination of vector potential (competence in virus transmission, host selection and/or preference and vector abundance) - overall, although potential vectors of YF (*Aedes metallicus*, *Aedes vittatus*, *Aedes aegypti*) are present at selected sites in West Pokot, they exhibit low vector competence for YF and Dengue viruses reducing risk of transmission of these diseases. Abundance and resting preference of *Aedes aegypti* and *Aedes bromeli* in selected sites provide insights for targeted adult vector control especially during emergency outbreak situations; and (2) Seroprevalence of viruses among the selected populations - we observed low circulation of Dengue virus (low risk of outbreaks) in West Pokot, evidence of low YF circulation, (although this cannot be confirmed due to lack of YF vaccination status for the 6 positive individuals) and evidence of circulation of Zika virus at 1% antibody prevalence. This risk analysis is critical to decision making on disease prevention/control and implementation of cost-effective targeted vaccination coverage and targeted vector control intervention and it will help to minimize the alarming re-emergence of dengue, YF and Chikungunya in East and Central Africa.

1.1.3 *Neglected tropical diseases (NTDs)*

Eco-toxicological investigations on *Schistosoma* host snails in freshwater streams in western Kenya: Schistosomiasis is an acute and chronic parasitic disease caused by trematode worms of the genus *Schistosoma*. People become infected when larval forms of the parasite are released by freshwater snails that represent the intermediate hosts. Despite the significant role of snails in disease transmission malacological studies are rare. The team is testing the hypothesis that pesticide pollution may favour the development and spread of host snails through the depletion of antagonistic macroinvertebrate species, affect the development of the trematodes in their intermediate hosts, and may reduce predators of the free-swimming trematode life stages. Over the past 12 months the team has mapped the study area, selected 50 diverse field sampling sites and implemented comprehensive sampling and habitat characterization studies to identify risk factors associated with the distribution of host snails and trematodes. Numerous pesticides including insecticides have been found in the tissue of collected host snails. The analysis of water pollutants in water samples is in progress. To date low levels of pesticides including neonicotinoid and carbamate insecticides were common in water samples. A snail culture was established and experiments on the effects of insecticides on the schistosome-host snail interactions are ongoing.

1.1.4 *Endosymbionts*

SymbioVector project: This project aims to determine the potential role of *Anopheles* mosquito symbionts for *Plasmodium* transmission-blocking to decrease disease burden in developing countries. The team succeeded in isolating two microbes of considerable interest from the perspective of transmission blocking: *Microsporidia* sp. and *Leptosphaerulina* sp. field collections and *Plasmodium* transmission experiments at Mbita-TOC have demonstrated that both prevent the malaria mosquito (*Anopheles gambiae*) from successfully transmitting the malaria parasite. Notably, *Microsporidia* sp. has a stronger blocking phenotype. These important findings should provide a path to developing a highly novel control strategy with transformative potential. Results showed that *Microsporidia* sp. and *Leptosphaerulina* sp. symbionts exhibit both vertical and horizontal transmission. Therefore, several dissemination strategies could be utilized. The team is currently investigating the mechanistic basis of protection (and potential synergy between the two symbionts) and also planning to develop a project to study symbiont dissemination under semi-field conditions.

1.2 Animal Health Theme

1.2.1 *Novel biopesticide formulations and attractants/ repellents for integrated tick management*

Field efficacy trials for registration of *M. anisopliae* isolate ICIPE 7, commercially known as Tickoff® were conducted in partnership with Real IPM Ltd., Kenya – in parallel with similar trials conducted by the Livestock Department of the Ministry of Agriculture, Kenya. More than 70% reduction in tick pressure or attachment in the treatment groups compared to the controls was observed at four weeks post-treatment. The Livestock

Department staff have already finished their evaluation of first field trial and are awaiting the next annual board meeting to make a decision on final product registration. *icipe* supported the field efficacy trials conducted by the Ministry of Agriculture by assessing the quality of the commercial product, Tickoff®. It is anticipated that after the outcome of the regulatory authority on the product in December 2018, large-scale dissemination activities will be undertaken with pastoralists.

1.2.2 *Integrating tsetse repellent technology for the management of tsetse flies and trypanosomiasis*

During the reporting period, the tsetse repellent technology received approval from the Kenya Pest Control Products Board (PCPB), paving the way for commercial production and distribution. The award of the certificate in May 2018 has enabled *icipe* to proceed with a commercialization plan that includes progressing towards a licensing agreement with a private sector company. Two new prototype dispensers (canvas-based and plastic material-based) will be evaluated as part of the scaling up. Registration and commercialization will allow for expansion beyond the pilot area of Shimba Hills National Park and also for scaling up beyond Kenya. In addition, scaling out operations to Zambia and Ethiopia are planned.

1.2.3 *Management of biting flies and trypanosomiasis in Camel*

A socioeconomic survey conducted to evaluate the impact of surra disease on camel health, productivity, and livelihood of pastoralists resulted in identification of trypanosomiasis as the number one constraint of camel health in three project sites i.e. Impala Ranch, Laikipia County, Ngurunit and Shurr, all in Marsabit County, northern Kenya, accounting for 77-90% of the mortality in different sites. Results indicated that camel trypanosomiasis is most probably caused by a complex of trypanosomes species (i.e. *Trypanosoma evansi, T. vivax* and *T. congolense*). Furthermore, the team identified the potential surra vectors in all three above mentioned sites, which include *Hippobosca camelina*, *Pangonia ruppellii*, *Tabanus* spp., *Stomoxys calcitrans*, and *Chrysops* species.

1.2.4 *Antibody clearance as a virulence factor in African sleeping sickness*

Analysis of feeding patterns of *Glossina fuscipes fuscipes* was completed and data indicated the importance of monitoring lizards, hippopotamus, humans and livestock as hosts. The proportion of hosts found was variable, and depended on sampling location, which provides a window into the level of influence of human activity (fishing, livestock keeping). The epidemiological significance of these findings is being determined.

1.2.5 *Zoonoses in a human-livestock-wildlife interface in the Maasai Mara National Reserve, Kenya*

Analysis of the diversity and abundance of mosquito, tick, and tsetse fly species, as well as of the pathogens (arboviruses, trypanosomes, tick-borne pathogens) they harbour in the Maasai Mara National Reserve has neared completion. Among diverse vector-pathogen-host relationships identified, notable results include: (i) a clear association of *Sodalis* endosymbiont infection with increased frequencies of trypanosome infection in tsetse flies; (ii) high rates of tsetse feeding on hippopotamus, with a complete absence of wildebeest in bloodmeals, despite the fact that samples were collected during the migration with high wildebeest populations; (iii) high rates of *Theileria parva* (the causative agent of East Coast fever) in questing *Rhipicephalus appendiculatus* ticks in the Reserve; and (iv) tick species-specific *Coxiella* endosymbionts are ubiquitous among sampled specimens, in contrast to their rare occurrence in ticks sampled at other sites in Kenya. Arbovirus screening and bushmeat analyses are ongoing.

1.2.6 *Sustainable peri-urban milk value chain development in Somaliland*

The Geo-Information Unit utilized time-series remotely sensed data sets from different satellite systems to produce the first comprehensive map on two invasive plant species (*Prosopis juliflora* and *Parthenium hysterophorus*) for western Somaliland (eastern Africa). Both crops have a negative impact on milk production: the prosopis population increased particularly around the river making it harder for the animals to have access to drinking water; and (ii) the Parthenium when eaten by animals generates bitter taste in the milk thereby reducing its commercial value. The team demonstrated that vegetation phenological/seasonality variables extracted from satellite imagery together with machine learning analytical tools can contribute to map the spread and distribution of invasive plant species in a dryland ecosystem in eastern Africa. Maps on the spread of invasive species can be used to identify risk, buffer and containment zones in support of strategies towards managing natural resources and invasive species.

1.2.7 Outcomes from the External Review of the Animal Health Theme

Three eminent scientists from Europe and North America reviewed the R&D achievements of the Animal Health Theme. The reviewers concluded that the combination of high quality basic science with clear translation of results is impressive and internationally competitive. One of the recommendations made by the review team was for *icipe* to put in place a clear strategy/position for how to be involved in development/extension activities. The team is strengthening efforts to move the scientific results to downstream applications. A clear example for this is the tsetse collar which has entered into a phase of field implementation and adoption by relevant communities. In addition, the review team also recommended expanding the epidemiology expertise in the group, which would also benefit the Human Health Theme researchers. *icipe* researchers will seek additional funds to explore the synergistic opportunities among the 4-H Themes to contribute to the Centre's One Health concept.

1.3 Plant Health Theme

1.3.1 Pests of horticultural and plantation crops

Identification of host marking pheromones for African fruit fly control: Host marking pheromones (HMPs) deposited by female fruit flies deter other females from over-exploiting the same fruit for egg laying. If identified, they can be exploited for fruit fly control. During a recent semiochemical studies of African indigenous fruit flies in the genus *Ceratitis*, the team documented host marking behaviour in *C. cosyra*, *C. rosa, C. capitata* and *C. fasciventris*. The team has identified HMPs in two of these fruit fly species: *C. cosyra* and *C. rosa*. The HMPs were isolated from the aqueous extract of adult female fecal matter and characterized by liquid chromatography–quadrupole time of flight–mass spectrometry (LC-QTOF-MS). The HMP of *C. cosyra* was identified as the tripeptide, glutathione and it deters egg laying in conspecific females and the heterospecific females of *C. rosa*, *C. fasciventris*, *C. capitata* and the melon fly *Zeugodacus cucurbitae*. The HMP of *C. rosa* was identified as the amino acid glutamic acid. Semi-field and field evaluations of these HMPs, as potential fruit fly integrated management tools, are underway.

Fruit fly IPM technology up-scaling and dissemination among smallholder fruit growers in East Africa: During the period under review, *icipe* in collaboration with National Agricultural Research System (NARS) in the different project sites in Kenya, Ethiopia and Tanzania trained an additional number of 87 NARS staff (Female 36%; Male 64%), 17 Community Extension Service Providers (CESPS) (Female 29%; Male 71%) and 744 growers (Female 28%; Male 72%). Import permit for introduction of two fruit fly parasitoid species (the egg parasitoid *Fopius arisanus* and Larval parasitoid *Diachasmimorpha longicaudata*) has been obtained from the Ethiopian Government and colonies of the two parasitoid species were initiated at *icipe*, ILRI Campus in Addis Ababa, Ethiopia. Training was provided on rearing of the two parasitoid species for NARS staff drawn from the Plant Health Clinic from Arbaminch, Hawassa University and the Ministry of Agriculture and Livestock Resources.

Integrated pest and pollinators management (IPPM) to enhance productivity of avocado and cucurbits among smallholder growers in East Africa: One of the objectives of this project is to characterize cucurbit- avocado production systems and mapping crops and cropping patterns in diverse agro-ecologies in Kenya and Tanzania. Time-series freely available satellite data at 10 m spatial resolution were utilised to characterize the vegetation dynamics in the study sites in Kenya and Tanzania. Vegetation dynamics maps based on normalized difference vegetation index (NDVI) were developed and three potential vegetation productivity scales (high, medium and low) were produced. These vegetation productivity scales will guide the selection of sampling sites and sample villages for implementing the activities on pollination, integrated pest management (IPM) and socioeconomic impact.

Management of plant parasitic nematodes: One of the promising methods to control root knot nematodes (RKN) that the team is investigating is the use of semiochemicals. The team conducted studies to elucidate and identify the semiochemicals that mediate RKN interaction with susceptible host plants - tomato (*Solanum lycopersicum*), spinach (*Spinacea oleracea*) and pepper (*Capsicum annum*). Using a series of laboratory olfactometer assays followed by chemical analyses, the team found that the host infective stage J2s (microscopic second stage juveniles) of the RKN *Meloidogyne incognita*, were more attracted to the root volatiles from tomato and pepper but not spinach relative to the control. The team identified various chemical classes of root volatiles (monoterpenes, sesquiterpenes, pyrazines and benzenoids) mediating J2 attraction. Of these chemicals, the benzenoids methyl salicylate (present in pepper and tomato) strongly attracted J2s, whereas thymol from pepper strongly repelled J2s. Pyrazines in spinach roots attracted J2s.

Additionally, specific non-volatile metabolites involved in J2 attraction to the site of root penetration in tomato plant were also identified. These include the phytohormone zeatin, flavonoids quercetin and luteolin and alkaloids solasodine and tomatidine. These metabolites elicited concentration-dependent responses in J2s relative to controls, but zeatin elicited the strongest attraction. Taken together, these findings provide insights into RKN-host plant interactions, thus creating new opportunities towards management of RKN.

1.3.2 *Pests of staple crops*

Identification of the candidate genes involved in host acceptance by *Cotesia sesamiae* in Kenya and discovery of new parasitoid: *Cotesia sesamiae* is a parasitoid wasp which is widespread in SSA and it has been used in biological control for controlling *Busseola fusca*, a major stemborer pest of maize and sorghum crops. However, a variation in parasitism success on different hosts has been shown among populations of parasitoids. In contrast to the *C. sesamiae* population from Mombasa - coastal Kenya (avirulent towards *B. fusca*), the *C. sesamiae* population from Kitale – inland Kenya (virulent towards *B. fusca*) is able to develop in *B. fusca*, but both develop in *Sesamia calamistis*, the main host of *C. sesamiae* in coastal Kenya. The team took benefit of the existence of the two populations in Kenya of *C. sesamiae* (Cs-Coast and Cs-Inland), showing contrasting differences in acceptance of *B. fusca*, to initiate an analysis to determine the candidate genes involved in host acceptance by the parasitoids. The team succeeded in crossing individuals from the two populations and then backcrossed the F2 males with females from Cs-Coast and Cs-Inland strains. Phenotypic characterization (host acceptance) of the progeny will be confronted to genotype in a QTL (Quantitative Trait Loci) analysis approach in order to identify candidate genes involved in host acceptance by *C. sesamia*. The ABC PaPoGen French ANR project (Adaptation in Biological Control: Parasitoid Population Genomics, 2012-2017) team has discovered a new braconid species, *Cotesia typhae*, with ecological speciation on the stem borer *Sesamia nonagrioides* (Lepidoptera: Noctuidae) in Kenya.

1.3.3 *Improving Push-pull technology*

Identification of pest resistant brachiaria genotypes for fodder and management of insect pests in smallholder cereal-livestock systems: Brachiaria grasses are grown as forage crops in SSA, with some genotypes being used in management of insect pests. However, spider mite, *Oligonychus trichardti*, has recently been reported as its major pest in the region. Eighteen brachiaria genotypes were evaluated to identify sources of resistance to *O. trichardti*, and to determine their adaptability to different environments in western Kenya, both under controlled and farmer field conditions. The parameters evaluated as indicators of resistance to pest damage included leaf damage, chlorophyll content reduction, plant height, leaf area, number of tillers and shoot biomass. The amount of rainfall played a role in reducing mite infestation and increasing biomass yield of the genotypes. Since this is the first documentation of interactions between *O. trichardti* and different brachiaria genotypes, we propose these genotypes as potential candidates for improved forage yields in areas prone to *O. trichardti* infestation in Africa.

Screening of brachiaria genotypes for drought tolerance for improving adaptation of push-pull system to climate change: In many parts of Africa, increasing drought conditions limit productivity of the multi-purpose brachiaria grass as fodder and for its value in pest management. We evaluated the morphological and physiological performance of 18 apomictic accessions of brachiaria in simulated drought conditions in a screen house. Based on the drought stress index (DSI) values for the measured parameters and principal component analysis (PCA) biplots, the following accessions were identified as relatively less affected under severe drought stress: 'Xaraes', 'Piata', 'Marandu', 'CIAT 679', 'Mulato II', and 'Mulato I'. Additional studies showed preference of these genotypes by stemborer moths for oviposition with no survival of the pests' immature stages. These drought adapted grasses could improve sustainability of cereal-livestock farming systems under conditions of increasing aridification.

Impact of push-pull cropping system on maize ear rots and mycotoxins: We conducted surveys in western Kenya and collected maize samples from push-pull and non-push-pull fields to determine the impact of cropping systems on occurrence of mycotoxigenic fungi and associated mycotoxins. Levels of aflatoxin and fumonisin were determined using Enzyme-Linked Immuno-Sorbent Assay (ELISA). *Fusarium*, *Aspergillus* and *Acremonium* spp. were the most prevalent fungal genera in maize samples from both push-pull and non-push-pull cropping systems. The population of *F. verticillioides* and *A. flavus* was significantly lower in maize samples from push-pull, with all the samples from push-pull having aflatoxin levels below the Kenyan threshold (10 μg/kg). Similarly, the proportion of maize samples with high fumonisin levels above the European Commission (EC) threshold (1000 μg/kg), which Kenya adopts, was significantly lower in samples from push-pull plots. Our findings further demonstrate the effective control of maize ear rots, aflatoxins and fumonisin with push-pull cropping system.

Geospatial analysis to guide the scaling of push-pull technology: The overall goal of the geospatial analysis was to guide the scaling of 'push-pull' technology in maize growing areas across Africa using striga risk maps. Striga risk maps were produced using an ecological niche modelling approach. Maize bio-climate, phenological and soil variables were utilised to generate striga risk maps. Combining the developed striga risk maps together with livestock and maize growing regions data sets in countries like Kenya, Tanzania, Ethiopia, Malawi, Zambia and Rwanda, the project identified the potential sites for scaling 'push- pull' technology in SSA.

1.3.4 *Integrated management of Fall armyworm*

Establishment of community-based Fall armyworm monitoring, forecasting, early warning and management system (CBFAMFEW) in east Africa: Effective and timely management of the Fall armyworm (FAW) is only possible if the farmers in eastern Africa are enabled to monitor and forecast FAW outbreaks and be informed about potential management options that could be undertaken. The project aims at establishing a community-based FAW monitoring and information sharing networks in six eastern African countries (Burundi, Kenya, Rwanda, Ethiopia, Tanzania and Uganda). *icipe* is responsible for the implementation of activities in Uganda, Rwanda and Burundi. In each target country National level training of trainers (ToT's) involving at least 15 agricultural extension officers from 5 key maize production districts were trained on the: (i) use of pheromone traps for FAW monitoring; (ii) use of Fall armyworm Monitoring and Early Warning System (FAMEWS) mobile app; and (iii) management of FAW through mechanical, cultural, habitat management (Push-pull and intercropping) and biological control options. The national ToTs workshops were followed with district level sensitization and community level training on FAW monitoring and management involving more than 30 farmers in each district. Currently data on FAW incidence collected by trained community-level focal persons through the FAMEWS app are being collated at sub-regional level to forecast FAW outbreaks for timely intervention. *icipe* and CABI contributed to the development of a FAW monitoring and management manual, which has been translated into French for partners in Burundi.

Diversity of Fall armyworm strains in east Africa: Globally two strains of FAW have been identified, the rice and maize strains, which differ in their host range, ability to perceive pheromone molecules and susceptibility to pesticides and *Bt*. Understanding the diversity and distribution of these strains in Africa is critical for effective management. In this regard, *icipe* has undertaken both molecular characterization of FAW populations and assessed the field efficacy of pheromone blends specific to the rice and corn strains in east Africa. Results indicated differential response of FAW moths in east Africa to rice and corn strain pheromone blends in different locations indicating the likely presence of the two strains in the regions. Molecular characterization of FAW population in east Africa, confirmed the presence of both the rice and maize strains in Kenya, while in Tanzania limited surveys indicate the presence of rice strain in Arusha.

Habitat management and diversity of maize cropping systems for the management of Fall armyworm: Based on the feedbacks from adopters of Push-pull who indicated reduced incidence of FAW in Push-pull farms as compared to monocropped maize, 250 push-pull adopting farmers in Kenya, Uganda and Tanzania were surveyed for their perception on impact of push-pull on FAW and the data were recorded on FAW incidence in climate-adapted push-pull farms and maize monocrop. Push-pull farms recorded 82.7% reduction in FAW incidence as compared to monocropped farms. Farmers also rated the technology to be significantly superior in controlling FAW. Further field evaluation of FAW incidence in maize-edible legume intercropped, push-pull and maize monocropped farms in Uganda confirmed the impacts of push-pull with more than 60% reduction in FAW incidence. It was also observed that intercropping with edible legumes such as bean, soybean and groundnut can provide more than 35% reduction in FAW incidence.

Development of biopesticide for Fall armyworm management: Biopesticides are effective alternatives to the use of synthetic pesticides in the IPM of FAW. In an effort to identify and develop potent biopesticides for FAW management, the pathogenicity of 21 fungal isolates from three different genera (*Metarhizium*, *Beauveria* and *Isaria*) were assessed against the egg stage of FAW. Results showed that isolates of *M. anisopliae*, ICIPE 78, ICIPE 40 and ICIPE 20 outperformed all the others by reducing the eggs hatchability by 87, 83 and 80%, respectively. ICIPE 78 has been already commercialized as Achieve® against spider mites by Real

IPM Ltd., and this could therefore be used as a potential ovicidal biopesticide to suppress FAW population in Africa. In addition to the egg mortality, the fungal isolates also induced deferred mortality to the newly emerged larvae from the fungus treated eggs. On larvae *Metarhizium anisopliae*, isolate ICIPE 7 outperformed all the others by causing 94% larval mortality. On adult *Beauveria bassiana*, isolates ICIPE 621 and ICIPE 676, and on *Metarhizium anisopliae*, isolates ICIPE 7 and ICIPE 315 were found to be highly pathogenic causing 100% mortality at 5 days of post inoculation. These isolates are being used to develop a "lure and infect" strategies for adult FAW management.

Community composition and functioning of Lepidopteran maize stem borers with the recent invasion of Fall armyworm: Three species of Lepidopteran stem borer (*Busseola fusca*, *Sesamia calamistis* and *Chilo partellus*) inhabit cereal crop either as single or as mixed species. The composition of these stemborer communities varies with location, altitude and season: *B. fusca* is abundant in the highlands, while *C. partellus* dominates in the lowlands. *Sesamia calamistis* is present at all altitudes in low numbers. In parallel, these stem borer pests are parasitized by their specific natural enemies, *Cotesia flavipes* and *C. sesamiae*. We hypothesize that the current spatial and temporal variations in maize stem borer communities and their associated parasitoids may soon change due to the invasion of a dominant and aggressive invasive FAW, *Spodoptera frugiperda*. Our preliminary observation showed that FAW is currently starting to interact and compete strongly with the other lepidopteran stem borer communities particularly at the early larval instars when the stem borers are mostly leaf feeders and occupying the same niche as *S. frugiperda*. Additional study is investigating the potential competitive displacement along with their associated parasitoids in two agro-ecological zones in Kenya.

Natural association of indigenous parasitoids on Fall armyworm in East Africa: Surveys for indigenous natural enemies attacking FAW have been undertaken in Ethiopia, Kenya and Tanzania. Results showed that one native egg parasitoid (*Chelonus curvimaculatus*) and 4 native larval parasitoids (*Charops ater, Coccigydium luteum, Palexorita zonata* and *Cotesia icipe*) have formed new associations with FAW in its new environment in Africa. Among these parasitoids, *Cotesia icipe* was found to be widely distributed with parasitism rates ranging from 5 – 45% which is very encouraging.

1.3.5 *Insects for food and feed*

Insect-based protein meal as a potential feed ingredient in layer chicks - Effects on growth performance, carcass quality and economic returns: This study was designed to evaluate for the first time the effect of substituting fishmeal (FM) with black soldier fly larvae meal (BSFLM) at different inclusion levels as protein source in chick and grower diets on weight gain, feed intake, feed conversion efficiency (FCE) and carcass characteristics. Higher growth performance of the chicks was achieved at lower inclusion levels of 25 and 50% BSFLM, compared with the growers' control lots. These results indicate that BSFLM is a good protein source for layer chicks. A higher cost-benefit ratio and better return on investment (ROI) was recorded when the birds were reared on the highest inclusion of BSFLM compared to the conventional diet which was more expensive.

Effect of black soldier fly feed meal on pigs: This study investigated the potential of replacing fishmeal with black soldier fly larvae meal (BSFLM) for pigs. Replacement of fishmeal with BSFLM did not affect the average daily feed intake (ADFI). Average daily weight gain (ADG) was similar in male pigs but was significantly higher in female pigs compared to control. The results indicate that BSFLM can serve as an alternative protein source for feeding growing pigs without adverse effects on growth performance.

A new edible cricket species from Africa of the genus *Scapsipedus* and its rearing on various diets: A new edible cricket species *Scapsipedus icipe* Hugel & Tanga was described from Kenya. The distribution, the acoustic behavior, including call and courtship song, mitochondrial sequences, and data on the biology have been established. The developmental time and survival rate of the different life stages varied considerably on the various diets, with the shortest development and highest survival rate recorded when fed with wheat bran diet. Body size was also significantly correlated with longevity of either sex on most of the diets. Females fed on protein-rich diets (fish offal, soybean and wheat bran) had significantly higher lifetime fecundity and fertility when paired with male partners of larger body size. Female-biased sex ratio was recorded on wheat bran, soya bean and carrot diets, whereas it was male- biased on maize and carrot diets. The results clearly indicated that the edible cricket is a very promising species for mass production for food and feed.

Analysis of dietary minerals, vitamins and heavy metals in edible insects of east Africa: In partnership with Food Security Centre, University of Hohenheim, the dietary minerals, vitamins and heavy metal contamination in fresh and processed edible insects in east Africa were assessed. Results indicated that the Saturniid caterpillars and edible crickets have significantly higher levels of calcium (591 – 1458 mg/ kg) and magnesium (1090 – 1599 mg/kg) as compared to long-horned grasshopper, *Ruspolia differens,* with 305 – 403 mg/kg of calcium and 386 – 401 mg/kg of magnesium. Dietary iron and copper contents were significantly higher in the edible grasshoppers and crickets as compared to the saturniid caterpillar. The edible insects were also rich in key vitamins such as β-carotene (1.82 – 49.7 mg/100 g), β-cryptoxanthin (0 – 5.96 mg/100 g), lutein (1.8 – 139.32 mg/100 g), zeaxanthin (0.9 – 10.9 mg/100 g) and riboflavin (Vitamin B2) (1.18 – 2.27 mg/100 g). Analysis for contamination of heavy metals indicated that mercury and cadmium were below detectable levels of 0.05 and 0.03 mg/kg, respectively, while lead contamination varied between 0.1 – 0.79 mg/kg.

1.4 Environmental Health Theme

1.4.1 *Sericulture*

Morphometrics and DNA barcoding of Eri and wild silkmoths: The team is undertaking morphometric studies of the Eri silkmoths, *Samia cynthia ricini* and *Philosamia cynthia ricini,* and their subspecies, with the aim of understanding their biology. The phylogenetic tree generated from the mitochondrial COI sequences indicate that the Eri silkmoths and subspecies are closely related despite different morphological features in their larval stages. The study indicates that Eri silkmoths may not be well differentiated using the mitochondrial markers, and hence the need to use nuclear makers. Further research is also focusing on other wild silkmoths, *Gonometa postica, Argema* sp., *Anaphe* sp. and *Epiphora* sp., from different ecological zones in Kenya in order to provide an understanding of the genetic variation that exists among them. This approach will open an avenue for investigating species distribution and abundance, which will contribute not only to the understanding of their biology and ecology, but also to their conservation and utilization for income generation in marginal areas of Kenya and beyond.

Life cycle and performance of eri-silkworm (*Samia cynthia ricini*): The goal was to understand the life cycle of *Samia cynthia ricini* and their preferred food plants in order to develop appropriate rearing protocols. Different food plants including *Ricinus communis* (castor), *Manihot escuelenta* (cassava) and *Morus alba* leaves (mulberry) were fed to the larvae and various parameters observed, including larval span, survival rate, larval, pupa and cocoon weights, fecundity, and hatchability. Results indicate *Ricinus communis* was superior to the other food plants tested in improving the rearing performance of eri silkworms. Further studies on various genotypes will be important in establishing the most preferred and appropriate food plant. Ongoing research is also focusing on the eri silkworm life cycle and performance in different ecological zones to provide basic knowledge for commercialization of eri silkmoths in Kenya and other regions across Africa.

1.4.2 *Bee research*

African bees' resistance to Varroa mites: Previous *icipe* research has shown that African bees are able to survive, without maladies inflicted by Varroa mites that have been known to contribute to the colony collapse disorder (CCD) syndrome. *icipe* researchers have recently published two papers that contribute to the knowledge on the reason for the resistance of African bees to Varroa. The first article showed a higher rate of grooming in African bees compared to European bees, attributed to the hygienic behaviour of bee colonies. Results from the second paper showed that African bees are able to detect Varroa infested brood cells, open them and remove the mites without harming the developing bee pupa.

Pollination efficiency among different stingless bee species on yield and fruit/seed quality in different horticulture crops: The team conducted a comparative study on bee foraging behaviours and pollination efficiency experiment in fruit production and seed quality set on greenhouse sweet melon using four categories of treatments; no pollination, self-pollination, hand cross-pollination and bee pollination. The bee species tested as pollinators were the African honey bee (*Apis mellifera scutellata*) and 7 stingless bee species (*Meliponula bocandei, Dactylurina schimdti, Plebeina hildebrandti, Meliponula lendliana, Hypotrigona gribodoi, Meliponula ferruginea* reddish brown and *Meliponula togoensis*). Results have shown that female flower excluded from any pollination did not set fruits. Heavier and voluminous fruits were obtained from female flower pollinated by hand cross-pollination and three stingless bee species (*P. hildebrandti*, *M. bocandei* and *H. gribodoi*), respectively.

Stingless bee species discrimination using molecular tools: The use of morphological features in the identification of stingless bees in the genus *Hypotrigona* is extremely difficult, due to many similarities among species, resulting in taxonomic ambiguity. The team applied both traditional morphometrics and DNA barcoding as complementary tools for the identification of three *Hypotrigona* species (*H. gribodoi, H. ruspolii* and *H. araujoi*) from Kenya. Results showed that morphometric analysis separated *H. gribodoi* and *H. ruspolii* from *H. araujoi* although there is an overlap between *H. gribodoi* and *H. ruspolii*. On the other hand, DNA barcoding separated the three species. The high genetic distance or intraspecific distance within *H. gribodoi* strongly suggests cryptic speciation within this species, and that the *H. gribodoi* collected from Mwingi is a putative new species. Thus, the use of morphometrics and molecular taxonomic approaches (DNA barcoding) provide a convenient, robust and reliable way to identify *Hypotrigona* species. It also indicates the need for a thorough revision of *Hypotrigona* species.

1.4.3 *Bioprospecting*

2.4.6 Integrated vector management (IVM) to improve health and livelihoods of communities in malaria-affected areas of Kenya and Ethiopia: "Uzimax", a plant-derived mosquito larvicidal product for vector control, is at the final stage of registration. Independent testing which include toxicity, efficacy and physico-chemical property studies were completed and a toxicity study report was submitted to the Pest Control Products Board (PCPB). A final summary dossier combining toxicity, efficacy and physical and chemical properties as a basis on which the award of certificate shall be made was presented to PCPB. The dossier and label have been endorsed to queue for presentation to the registration board which meets quarterly in a year.

Up-scaling sustainable commercial production of medicinal plants by community-based conservation groups at Kakamega forest in Kenya: The project aims to transform the on-going community-based commercial production of medicinal plants and derived products at Kakamega forest in Kenya into micro, small and medium-sized green social enterprises (MSMEs) to enhance livelihood improvement and environmental conservation. The project developed three training manuals on entrepreneurship, access to finance and cooperative formation and simplified them into three toolkits. An MOU was signed with a private-partner, Milba-Brands Associate Ltd., to undertake sales and marketing of Naturub range of products for sustainable sales for the community. To promote biodiversity conservation efforts, 300 community members undertook planting of pollinator plants in their homesteads and on their farm hedgerows. The project has developed 16 toolkits on sustainable consumption and production of medicinal plants, health and safety and distributed 3,108 copies of the toolkit of *Ocimum kilimandscharicum* as an empowerment tool for use by farmers.

Sustainability of medicinal plants-based enterprises and bio-monitoring of environmental health for targeted communities in Kenya and Tanzania: The project aims to ensure that successful measures are in place to enhance the sustainability of the community-based insecticidal and medicinal plant enterprises, bio-monitoring of environmental health, pollinator conservation and youth sensitization in Kenya and Tanzania for livelihood improvement and biodiversity conservation.

2 R&D Units, Programmes and Country Offices

2.1 Social Science and Impact Assessment Unit

2.1.1 *icipe wide Planning, Monitoring, Evaluation and Learning (PMEL) Strategy document*

icipe has been engaged in developing a monitoring and evaluation (M&E) system. The strategy has been reviewed and endorsed by United Kingdom's Department for International Development (DFID), one of *icipe*'s long-term strategic donors/partners. The strategy is based on self-assessment of *icipe's* current M&E system by *icipe* researchers and professional staff and the shared vision of the M&E system that they would like to have in place in five years' time. Currently, *icipe* implements a conventional M&E system to ensure proper utilisation of financial resources through monitoring of action plans and budgets. The new strategy integrates planning and learning to support adaptive management more effectively. The strategy assumes that *icipe* will achieve its objectives through three interlinked impact pathways, namely: (i) technology development and adoption; (ii) capacity development; and (iii) policy influence.

The PMEL strategy has also identified a set of *icipe*-level key performance indicators (KPIs) against which the Centre will assess and demonstrate its aggregate progress along the three identified impact pathways. The selected thematic KPIs include: (i) contributing to Africa's agricultural transformation through insect science and partnership; (ii) contributing to system capacity development for change; and (iii) influencing the global and regional insect science and policy agenda. Besides the thematic KPIs, *icipe* also has strategic KPIs related to organisational effectiveness and communication for impact.

2.1.2 *The effect of technology adoption on intrahousehold allocations: A case of push-pull technology in western Kenya*

This project used primary data collected from 711 farm households to assess the impact of push-pull technology (PPT) adoption on gender specific resource allocations and gender roles of men and women from maize producing households in Western Kenya. PPT adoption significantly reduces labour requirements during ploughing, weeding and threshing but significantly increases labour hours for harvesting. In comparison to men, women save more labour hours, during weeding and threshing but less during ploughing due to PPT adoption. Similarly, whereas PPT adoption increases harvesting labour requirements for both men and women, the incremental change is lower for women than for men; women labour allocation to harvesting on PPT plots increases by 22.6% compared with 26.7% increase for men. The results also revealed that adoption of PPT increased child education investment and shifted household expenditures towards goods associated with female consumption preferences.

2.1.3 *The nutrition impact of women empowerment in Kenyan agriculture - Application of the multinomial endogenous switching treatment regression*

The study utilizes data obtained from a random sample of 711 cereal growing households in western Kenya to assess the impacts of women empowerment in agriculture individually as well as in combination with push–pull technology (PPT) on women and household nutritional status. The analysis showed that women empowerment has a positive and significant effect on women and household dietary diversity scores. The impact is significantly higher for empowered women belonging to PPT-adopting households than for their counterparts who have not adopted PPT. Similarly, disempowered women from PPT-adopting households have higher dietary diversity scores compared with disempowered women from non-adopting households. These results imply that individual and household welfare could be enhanced to a greater degree by combining women empowerment with technology adoption than by treating the two elements as separate development issues.

2.1.4 *Further development and uptake of push-pull technology (PPT)*

Implementation of wide-scale dissemination of PPT in eight countries (Kenya, Uganda, Ethiopia, Tanzania, Malawi, Rwanda, Zambia and Zimbabwe) has directly reached 25,284 smallholder farmers adopting the technology, cumulatively bringing the total number of push-pull adopters to 207,058. In addition, approximately 5.1 million beneficiaries were indirectly reached through efforts of partners and farmer to farmer disseminations as well as mass media. Adoption and impact studies revealed increased intensity of adoption of PPT resulting in poverty reduction through increased benefits from maize yield per unit area, income, and per capita food consumption. Furthermore, surveys from the various countries demonstrated that the PPT is effective in controlling Fall armyworm (FAW) and represents the first documented evidence of a technology that can be immediately deployed for management of this invasive pest throughout Africa.

2.2 Technology Transfer Unit

2.2.1 Push-Pull Technology in sub-Saharan Africa

The current project is articulated through four significant activities including strategic partnerships, ensuring availability of seeds, dissemination pathways and monitoring and evaluation. Beyond East Africa, the project is now being scaled out to eight countries (Zambia, Malawi, Zimbabwe, Rwanda, Burundi, Ghana, Senegal and Burkina Faso). *icipe* is currently supporting local seed production of push-pull companion plants through community engagement in addition to working with private sector partners and model private farmers in Rwanda, Zambia and Zimbabwe. Several dissemination pathways are being employed to disseminate the technology. These include the establishment of learning sites, field days, the use of cascade models with lead farmers, training of trainers (ToTs) and extensive use of media. Monitoring and evaluation work has focused on assessing agronomic parameters, socio-economic drivers as well as landscape level of intervention with the mapping of striga and livestock production areas to guide the project implementation. With the invasion by the Fall armyworm (FAW), the demand for the technology has tremendously increased, with requests from several other countries (Eritrea, DRC, Mozambique, Cote D'Ivoire, Mali and Niger).

2.3 BioInnovate Africa Programme Phase II

The Programme is currently providing innovation grants to 20 regional project teams from six target countries (Burundi, Ethiopia, Kenya, Rwanda, Tanzania and Uganda). The Project teams comprise university or public research institute scientists working collaboratively with their counterparts in industry and business to commercialise innovative biologically-based technologies, inventions and research ideas. The Programme's three thematic areas are: value addition to agro-produce and related biological resources, bio-waste conversion, and bioeconomy policy engagement.

2.3.1 BioInnovate Africa Fellowship for Women Scientists

A total of 12 women scientists were competitively selected by an independent committee and awarded Fellowship attachments to the various BioInnovate Africa Programme (BAP) projects. The four months Fellowships were granted for the period between 15 September 2018 and 31 August 2019.

2.3.2 Trainings, workshops and seminars

Several training workshops on business incubations, private sector engagement, gender integration and importance of bioeconomy were held during the reporting period.

2.4 *icipe* - Ethiopia Country Office

The *icipe* - Ethiopia country office currently hosts 39 staff members (16 of them based in the field sites across the country) including four postgraduate students. During the reporting period, the Ministry of Agriculture and Livestock Resources of Ethiopia awarded *icipe* certificates of excellence for pioneering and scaling efforts on push-pull technology and modern beekeeping in Ethiopia. Two projects, one on beekeeping and the other on silk farming were recommended for funding by the World Trade Organization (WTO) of the United Nations through the Enhanced Integrated Framework.

2.4.1 Project highlights

Rice, maize and chickpea IPM for East Africa: Currently, over 2,000 men and women farmers are directly involved in demonstrating rice, maize and chickpea IPM technologies in the 3 project countries (Ethiopia, Kenya, Tanzania). The technologies being promoted include: (i) push-pull for maize IPM; (ii) biopesticides and botanical extracts for rice IPM; and (iii) seed dressing, soil water drainage, biopesticides and botanical extracts for chickpea IPM. About 50,000 farmers are currently aware of the rice, maize and chickpea IPM practices/technologies in the 3 target countries.

Creating strategic linkages for increased production and wider application of push-pull technology in East Africa (BiomassWeb): Results from push-pull versus control plots revealed that households obtained better maize yields from push-pull than maize monocrops by 36.5% and 46.7% in stemborer and striga infested districts, respectively. Livestock fodder production of 16.7 kg m^{-1} of *Brachiaria* as grass and 9.3 kg m^{-1} of *Desmodium* as legume contributed to increased milk production from 1.5 to 3.0 liters cow^{-1} day^{-1}. Household survey showed that majority (92%) of the technology practicing farmers reported that push-pull technology is superior to their own farming practices.

Implementation of integrated vector management (IVM) interventions and its impact on community health, livelihood and its sustainability beyond project lifespan: Comprehensive IVM interventions including distribution of bed nets by government, larval source management, larviciding with Bti and community mobilization, were implemented covering an estimated 22,000 people through training, workshops, community-wide events and school anti-malaria campaigns. Malaria vector (mosquito) density has decreased by 80% and malaria case prevalence has decreased by 70% in 2018 compared to 2016 in target locations.

Young entrepreneurs in silk and honey (YESH): In its third year, the YESH project enrolled 4,000 additional youth in apiculture areas and another 1,100 youth in sericulture areas, with an approved annual budget of US$3.3 million. The project expanded to 11 new project sites (districts), in addition to the existing

6 districts where the project has been operating. Altogether about 5,100 youth (39% females) have been engaged and trained and provided with starter kits. Two regular meetings of the project National Steering Committee were successfully held. Eleven model apiculture sites have been initiated to serve as training and demonstration sites. Preparations were finalised to undertake independent mid-term evaluation of the YESH Project during the last quarter of 2018. A new MoU was signed between *icipe* and Africa Oil Ethiopia BV to support small irrigation kits to six model youth silkworm farming enterprises at YESH project sites. Additionally, about 728 youth groups/enterprises and 8,722 youth members have directly benefitted through the YESH project. During this reporting period, the Biovision Foundation supported pilot beekeeping project was also launched in Wag Himra Zone. Within the first 6 months, 300 youth were recruited, engaged and supported to establish 30 youth beekeeper enterprises, and have started operations on site as planned.

3 Capacity Building and Institutional Development (CBID) Programme

3.1 Post-graduate, Postdoctoral and Research Internship training

icipe had 82 PhD scholars (48 ARPPIS and 34 DRIP PhD scholars), 56 DRIP MSc scholars, 9 Postdoctoral fellows, and 52 Research Interns during the reporting period. 46% of postgraduate and postdoctoral fellows and 63% of Research Interns were women.

Completion: Two ARPPIS PhD scholars, six DRIP PhD scholars and 14 DRIP MSc scholars defended their thesis or graduated during the reporting period.

Country diversity. Seventeen African nationalities (Benin, Burkina Faso, Cote d'Ivoire, Cameroon, Democratic Republic of the Congo, Ethiopia, Ghana, Kenya, Nigeria, Rwanda, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe) and three non-African nationalities (Germany, Mexico, Oman) were represented in the postgraduate and postdoctoral programmes during the reporting period (Figure 1). The Internship Programme hosted interns from Kenya, Cameroon, DRC, Nigeria, Togo, USA and UK; of whom 77% were Kenyan.

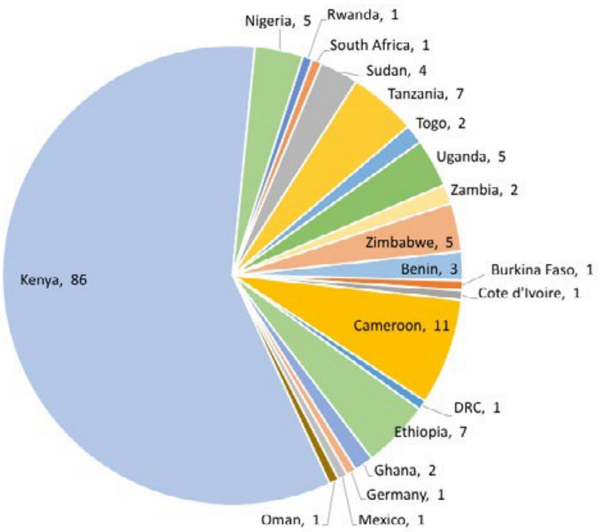

Figure 1. Nationalities and numbers of Postgraduate and Postdoctoral Fellows at *icipe*. 17 African, and 3 non-African nationalities were represented. 59% of Postgraduate and Postdoctoral Fellows in the reporting period were Kenyan.

Publications. Postgraduate scholars and postdoctoral fellows continue to make a major contribution to the publication output of *icipe*. Close to 50% of the 151 peer-reviewed papers published during the reporting period were first-authored or co-authored by postgraduate scholars or postdoctoral fellows.

Conferences: Fifteen postgraduate scholars presented papers at international conferences, including five ARPPIS scholars who presented at the 34th International Society of Chemical Ecology (ISCE) meeting in Budapest, Hungary (12-18 August 2018).

3.2 ARPPIS PhD scholarships 2018

The 2018 ARPPIS PhD scholarships call was open for three weeks in Jan-Feb 2018. The call was sent to >12,000 contacts in the CBID mailing list and announced on the *icipe* website and social media to ensure a wide distribution across Africa. We received 475 applications for PhD projects at *icipe*; the largest number received for any ARPPIS scholarships call. DAAD offered PhD scholarships to seven candidates: three women and four men from six SSA countries: Cameroon, Kenya, Nigeria, South Africa, Zambia, and Zimbabwe. The new scholars joined the ARPPIS PhD programme in September 2018.

3.3 Training courses/ workshops/ conferences organized by CBID Programme

The training courses/workshops and conferences organized by CBID within the reporting period had a total of 262 participants (59% women) from Benin, Burkina Faso, Burundi, Cameroon, Ethiopia, Ghana, Ivory Coast, Kenya, Nigeria, Rwanda, Sudan, South Africa, Tanzania, Togo, Uganda, Zambia and Zimbabwe.

3.4 Alumni tracking

By strengthening the research capacity of universities and research institutions in Africa, alumni of the *icipe* postgraduate programmes are playing an important role in the multiplier effect of capacity building. Of the 42 ARPPIS and DRIP PhD students who completed in 2015-2018 period, we are able to trace 35 (83%) working as lecturers/researchers/postdoctoral fellows/assistant professors in universities/research organizations in Africa; four (10%) are postdoctoral fellows outside of Africa; two (5%) are seeking postdoctoral fellowships; and one (2%) has left R&D to pursue career in business sector (Figure 2).

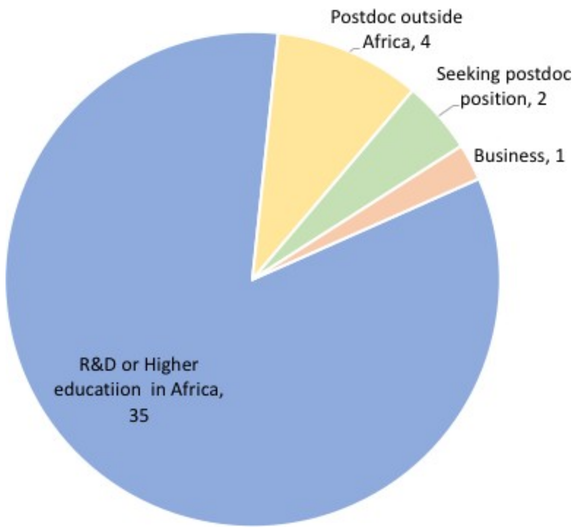

Figure 2. A recent tracer study of 42 PhD scholars who completed in 2015-2018 period, showed 83% are engaged in R&D and higher education in Africa.

SECTION 3: Results Based Management (RBM) Framework: Programmatic Progress Report For 2018

3.1 Human Health Theme: Progress Report as per RBM Framework Plan

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
Objective 1: 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.	WHO-AFRO and ICIPE signed a Technical Service Agreement (TSA) for an initial 4 disbursements of funds to ICIPE with a total amount of US Dollars 838,311, for the period 11 July 2018 – 31 July 2019. Following the funds release GEF/UNEP/WHO funds in 2018, icipe constituted a full technical team of 6 staff comprising of: 2 senior scientists (up to 50% staff time coverage), 2 newly-recruited full-time post-doctoral fellows; 2 ARPPIS PhD students to be based in Zambia. The icipe technical team has since September 2018 been guiding the implementation of IVM demonstration projects (house screening and winter-larviciding) in Botswana, Namibia, Swaziland, Zambia, Mozambique and Zimbabwe. New funding was secured by icipe from NORAD, currently focused on the continuation of IVM research and capacity building activities in Ethiopia for the period 2018-2022.	*icipe* now has an opportunity to significantly expand 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.	Number of community members trained. Number of combinations of vector control methods (non-chemical/chemical) being used at community level.	The full range of IVM research and capacity-building activities implemented in Kenya and Ethiopia during 2017 continued up to the end of 2018. This included updating of IVM stakeholder registers on a regular basis in all three project sites in Kenya and Ethiopia. Progress with publication of manuscripts was as follows: **<u>Accepted</u>** Kibe LW, Habluetzel A, Kamau A, Gachigi JK, Mwangangi J,	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

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
	At least 60% decrease in malaria prevalence and mosquito densities in target areas by 2018.	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.	Mutero CM, Mbogo CM. Low awareness and misconceptions of immature mosquito stages hinders community participation in integrated vector management in Malindi, Kenya. *Journal of Public Health and Diseases (Accepted – for publication in 2019).* Ng'ang'a PN, Mutunga J, Oliech G, Sune A, Mutero CM. Community knowledge and perceptions regarding screening of house eaves against mosquito entry in Nyabondo, Western Kenya: Preliminary observations. *BMC Public Health (Accepted – for publication I n2019).* **Submitted** Diiro GM, Kassie M, Ledermann ST, Muriithi BW, Mutero CM. Gender heterogeneous effects of malaria risk on agriculture productivity: Empirical Evidence from Rural Ethiopia. *Agricultural Economics (Submitted 2018).* 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).*	interested in promoting health research.
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	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	*icipe* consolidated its position as the lead institution for research aimed at demonstrating and strengthening of IVM in six southern African malaria elimination countries still using DDT for malaria vector control. Drafting of in-country project countries was initiated and three out of six such protocols submitted for ethical clearance.	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.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
	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.	IVM interventions in the context of AFRO-II project Global Environment Facility (GEF)/UNEP- through the main Executing Agency is WHO-AFRO.		
At least two chemical-based technologies for surveillance and/or disruption of malaria transmission developed.	Odour-baited traps tested for malaria control in at least one community by 2015. 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.	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.	Semi-field studies were implemented testing individual components of the push pull system highlighting the need to implement more research for the development of a trap that is attractive enough to compete with a human; A double blinded trial using a randomized block design was implemented in a rice irrigation scheme to test the impact of a push pull system on entomological outcomes; An acceptability study and willingness to pay for push pull products was completed. Several vector species were compared for their response to odour-baited traps. 1 proposal was developed for Unitaid under Grant Agreement Development (later declined) Novel traps are currently used for various vector monitoring activities under research programmes.	Further basic research required to develop functional push-pull concept, this includes the identification of odour-oriented behaviour of malaria vectors to spatial repellents, replacement of CO_2 in traps, placement of traps in space for optimal interaction, airsampling to better understand diffusion of chemicals in space and over time. Urgent need to develop more attractive blends for traps, current blends cannot compete with

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
		Availability of a potent spatial mosquito repellent or repellent principal. Number of publications in peer reviewed journals. Project progress reports. Theses. Posters.		human being in direct comparison. Human landing catches as the golden standard for estimating biting rates need to complement monitoring efforst for developing odour-baited trapping technologies, are however extremely difficult to implement and ensure data quality.
Innovative application strategies of novel, persistent insecticides for *An. gambiae* developed.	Optimum concentration of insecticides for malaria control used by the communities in western Kenya by 2020. An 'attract-and-kill' strategy adapted by combining oviposition attractants with long-lasting larvicides developed and used by communities by 2020.	Increased interest in larval source management by national malaria control programmes (NMCPs). Rationalised larval source management strategies for malaria control. Use of novel insecticides in national programmes. No. peer-reviewed publications. Books. No. theses produced.	Insect growth regulators were tested for attract and kill approaches in semi-field settings will limited success. One manuscript submitted. Increased interest of governments to use larval control tools for malaria control has been indicated by their inclusion of the tool in national strategy guidelines and also increased interest at RBMs Larval Source Management work stream (lead by Dr Fillinger, icipe). Partnership developed with Aquatain Ltd, Australia – formulation of silicone-based surface film combined with oviposition attractant cedrol to test a novel attract and kill strategy – small scale semi-field tests ongoing. 1 PhD student enrolled in 2017 to work on the association of swamp grasses and habitat selection by gravid malaria vectors to search for novel oviposition attractants for use in attract and kill. Novel olfactometer bioassays developed. New project on oviposition attractant funded by Swedish Research Council started in 2017.	Increased interest by donors and governments to use larval source management for malaria control specifically in elimination context. Need to develop tools that are easy to use and can complement front-line interventions. Novel product on market that have potential but need rigorous testing.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
Studying the egg-laying behaviour of primary and secondary malaria vectors to develop novel attract and kill strategies (2017-2020).	Protocols for rearing *An. funestus s.s.* and secondary vectors developed, and colonies established at *icipe* Thomas Odhiambo Campus (ITOC), Mbita Station, 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.	Anopheles funestus s.s. and 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. Peer-reviewed publications.	1 PhD student and 1 MSc student recruited. Protocols for establishing *Anopheles funestus* s.s. colony developed, and rearing initiated from field samples; to date successful in rearing F1 generation, Routine bioassays and olfactometer tests developed. Olfactometer calibration bioassays completed; system ready for testing novel substrates informed by field surveys. Protocols for field work to identify swamp grasses developed, field work scheduled for May/June 2018.	Rearing of An. funestus s.s. challenging – major issue to resolve is mating to get beyond F1 generation. Need for sending staff to South Africa to learn from group with established colony. Intensive surveys needed to find breeding sites for secondary vectors. Lack of knowledge on ecology of these species makes it difficult to locate them.
The symbiotic microbes harboured by mosquitoes as potential tools to control malaria transmission	Detailed survey of the symbiotic microbes associated with vector mosquitoes.	No. peer-reviewed publications.	Publication of Spiroplasma results; Chepkemoi ST, Mararo E, Butungi H, et al. Identification of *Spiroplasmainsolitum* symbionts in *Anopheles gambiae* . *Wellcome Open Research*. 2017;2:90. doi:10.12688/wellcomeopenres.12468.1.	The logistics difficulties and costs associated with transmission assays can be significantly reduced by collaborating with other

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
investigated.	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.		Experiments to determine the effect of *Spiroplasma* on Plasmodium transmission are ongoing. Discovery of a novel microsporidian parasite of Anopheles mosquitoes with transmission-blocking capabilities.	research teams that are carrying out similar work.
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.	MSc Thesis submitted A 3-component blend as improved lure for malaria vectors developed 1 article published.	
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 end of 2017.	Accreditation certificate Number of staffs trained in Biosafety.	Fully functional Arthropod Containment Level 2 Facility completed and equipped with state-of-the- art molecular biology equipment. A comprehensive Biosafety Manual and several essential standard operating procedures (SOPs) developed. Facility accredited and approved by the Kenya National Biosafety Authority for implementing research on genetically modified arthropods.	
Conduct studies on the genetic structure of the key malaria vector,	Knowledge on the genetic relatedness of different	Number of peer-reviewed publications.	Bionomics of *An. funestus* mosquitoes in contemporary malaria transmission in Kenya established Genetic population structure of *An. funestus* s.s. elucidated	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
Anopheles funestus by 2018.	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.		1 article published.	
Objective 2: Epidemiologic assessment of risk of yellow fever (YF) and dengue (DEN) transmission and outbreaks in Kenya.				
Objective 2.1. To determine existence and locality of YF, DEN transmission foci in Northern Kenya at border with endemic countries.				
Disease risk identified in study locations and verified.	Research team confirms presence/absence transmission between primate and human populations through vectors.	Publication. Report to donor.	One manuscript on serologic survey accepted for publication in Virology Journal on 6th May 2019. Donor report drafted for submission. Additional primate samples collected from the field for analysis in Feb 2019.	
Objective 2.2. Assess vector species presence and their YF/DEN vector potential in the selected areas in Northern Kenya.				
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.	Vector distribution and vectoirial capacity completed in Pokot and Turkana. One paper reporting the distribution and vectorial capacity of W. Pokot population was published in *Acta Tropica* journal in July 2018.	
Objective 2.3. To assess the potential for urban *Aedes* vectors to sustain an outbreak in major urban centers in Kenya.				
	The researchers identify the competent and refractory vector populations for transmission of YF and DEN.	Publications. Donor and other reports. Stakeholder information sharing meetings.	Vector distribution, and vectorial capacity data in three major cities determined. One manuscript detailing vector distribution and vectoral capacity in three major cities in Kenya submitted for consideration to POLOS-NTD. Donor reported drafted for submission soon.	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
Objective.2.4. 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.	Effect of skin volatiles of non-human primates in relation to humans on *Aedes* trap catches evaluated. Chemical profiles of the skin odor of NHPs and human established. Constituents of the odor profiles detected by *Aedes aegypti* established. Signature cues of NHPs and humans established as well as behavioral effect on *Aedes* catches in sylvatic and domestic settings. 1 manuscript drafted.	
Objective 3. Understanding the risks and benefits of newly developed irrigation schemes in western Kenya in the context of malaria elimination				
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.	Mosquito breeding habitats on farmlands and grasslands have been mapped. Remote sensing used to map cropping patterns.	Entry point of projects into community (including engagement of community and leadership as project starts in study area) is important to ensure support and participation of community in project activities. Feedback of project activities to communities and community leadership and stakeholders such as county government is important for sustaining

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
		Stakeholder information sharing meetings, workshops and focus group discussions. Conference presentations Progress reports.		project activities within the community.
Association between irrigation and malaria vector abundance, seasonality and biting patterns and sporozoite infection established over a 3-year period.	Improved awareness of the association between irrigation and vectors by all project stakeholders by end 2020.	SOP developed. Training field assistants on adult mosquito sampling. Sentinel households identified. Comprehensive dataset on adult malaria vectors, other mosquitoes and changes in species composition, seasonality and biting pattern compiled over 3 years. Multivariate risk factor analyses implemented annually. Publications and conference presentations. Stakeholder information sharing meetings. Progress reports	Adult mosquito collection from sentinel households during the dry and rainy seasons is ongoing. Molecular analysis of collected mosquito samples is on-going.	Entry point of projects into community (including engagement of community and leadership as project starts in study area) is important to ensure support and participation of community in project activities. Feedback of project activities to communities and community leadership and stakeholders such as county government is important for sustaining project activities within the community.
Association between irrigation and socio-economic and behavioral factors and malaria established over	Improved awareness of the association between irrigation and socio-economic factors and malaria by all project	SOP developed. Ethical approval granted for study.	Routine surveys to collect data on household socio-economic status and malaria prevalence is ongoing. Malaria surveys are conducted in the dry and rainy seasons.	Entry point of projects into community (including engagement of community and leadership as project starts in study area) is

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
a 3-year period.	stakeholders by end 2020.	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.		important to ensure support and participation of community in project activities. Feedback of project activities to communities and community leadership and stakeholders such as county government is important for sustaining project activities within the community.
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.	Remotely sensed data to understand the distribution of water bodies and cropping patterns in the study sites is ongoing. Analysis of this data is ongoing.	Entry point of projects into community (including engagement of community and leadership as project starts in study area) is important to ensure support and participation of community in project activities. Feedback of project activities to communities and community leadership and stakeholders such as county government is important for sustaining project activities within the community.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
		Stakeholder information sharing meetings. Progress reports.		
Effectiveness of intermittent irrigation evaluated. Effectiveness of monomolecular surface film evaluated.	Recommendations as to where and under which circumstances these control tools might be useful in irrigation systems compiled by end 2020.	Successful field surveys implemented. Database compiled. Publications and conference presentations. Stakeholder information sharing meetings. Progress reports.	To be done in 2019-2020.	
Objective. 4. Understanding freshwater pollution and the links to the distribution of Schistosoma host snails in Western Kenya				
Risk factor analyses implemented. 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.	2 PhD students recruited Protocols developed. Field sites identified. One field campaign completed. Dataset compiled for first field campaign; data analysis ongoing. Pesticide analysis completed in Nairobi and sample analysis ongoing in Germany.	Freshwater habitats in western Kenya polluted by diverse pesticides. Snail populations challenging to sample and Schistosoma infection low.
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.	SOPs for toxicity tests developed. Snail colony established at ITOC.	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
		Donor and other reports. Thesis chapter.		
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.	Trematodes will be determined using molecular techniques.	
Experimental assessment of impact of pollution on predator-prey relationships, snail vector competence and parasite survival.	Risk of schistosomiasis based on habitat pollution assessed for predicting disease risk by 2020.	Macrocosm experiments established and completed, Database established, Publications. Donor and other reports. Stakeholder information sharing meetings.	Macrocosm experiments under semi-field conditions.	
Objective. 5. Investigating the disease ecology of tungiasis (sand flea disease) for the development of treatment and prevention strategies				
Risk factors associated with disease identified.	Improved awareness of the association between certain environmental, socio-economic and behavioural risk factors	Ethical approval for study. Field surveys completed. Dataset compiled for analysis.	Community and school surveys.	Tungiasis is highly associated with poverty indicators and poor housing conditions.

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons Learned during 2018
	and disease by all project stakeholders (scientists, Ministry of Health, communities) by end 2018. Recommendations for prevention articulated by end 2018.	Statistical analysis. Publications. Donor and other reports. Proposals for prevention trials developed.		Simple interventions such as solid floors in home could prevent the disease. Concrete floors are too expensive for affected, resource poor. communities to afford and new technology needs to be developed.
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.	Clinical surveys in schools.	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
		Donor report. Publication. Proposals for phase III study.		
Impact of novel prevention tools known.	Recommendations for prevention made to Ministry of Health for incorporation in the Kenya National Guideline for Tungiasis Control by end 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.	Field samples. Development and testing of novel floor materials. Testing of neem solution and pyriproxyfen (insect growth regulator) for control of off-host stages of sand fleas.	
Objective 6 – Surveillance of arbovirus and mosquito vector diversities and their blood-meal host populations.				
Development of a cost-effective multiplex PCR-HRM assay	Discovery of Wesselsbron virus and diverse insect-specific flaviviruses in mosquitoes. Identification of diverse arbovirus infections in mosquitoes, livestock, wildlife and humans.	Proposals developed. >10 students trained 5 peer-reviewed publications.	Two additional students trained. Publication in review identifying dengue serotype 2 virus in mosquitoes sampled in human wildlife interfaces.	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
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.	Funding obtained to implement investigations (ANTI-VeC).	
Objective 7 – Understanding leishmaniasis transmission dynamics in Kenya and development of control strategies				
Specific objective 7.1: 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.	A manuscript submitted to Plos Pathogen (under review). Presentation made at Gordon Research Conference & 67th ASTMH. Project report submitted to the donor (NRF).	Management of collaborators and their expectations. Proper budgeting.
Specific objective 7.2: To develop an odour baited sandfly attraction trapping device - the "SanTrap" for the control of leishmaniasis				
Development of odour baited sandfly attraction trapping device - the "SanTrap" for the control of leishmaniasis.	Novel approach in the control of sandfly bites developed. Efficacy and efficiency of the attract-and-kill tool on sandflies established.	Publications. Reports. SanTrap tool Patent.	Standardization and evaluation of the tool on going. Presentation made at ASTMH conference. Project report submitted to the donor (Wellcome Trust).	Procuring of some materials takes time and with stringent regulation therefore to initiate the procurement process early enough. Study community perceptions.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
Specific objective 7.3: Epidemiological factors associated with cutaneous leishmaniasis transmission in Gilgil, Nakuru County, Kenya.				
Vector species for Cutaneous leishmaniasis and parasite transmission in Gilgil, Nakuru County identification	Identification and mapping of cutaneous leishmaniasis vectors. Ecological factors mapping. Cutaneous Leishmania reservoir identification	Publications. 1 MSc. Stakeholder information sharing meetings.	1 MSc student successfully defended his thesis and graduated from Liverpool School of Tropical Medicine. A paper accepted for publication by Plos Pathogen.	

3.2 Animal Health Theme: Progress Report as per RBM Framework Plan

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
Objective 1: 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.				
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.	Spatial repellent blend reduced trapping efficiency by 60%. Feeding efficiency also reduced by ~60%. Prototype dispensers evaluated.	One repellent for vectors of surra developed, consisting of a blend of repellent compounds (acetophenone, 4-methylacetophenone and 2-hydroxyacetophenone) formulated on Nano-polymer beads dispensers. These are delivered via tygon tubing. A formulation of attractants (p-cresol and carvone) that is deployed where camels congregate (camel bomas and watering points). Demonstration of maternal transmission of surra, indicating the need for diagnose & treat or prophylaxis.	Working with the community is essential. Contribution to the study and enthusiasm generated demonstrate interest at community level for uptake of the technology. Engaging industry partner will accelerate technology development, particularly dispenser design and deployment.
Investigate the impact of trypanosomes on host animal semio-chemicals change.	Trypanosome induced semio-chemicals identified.	Potential biomarkers identified for trypanosomosis diagnosis.	Phenolic compounds concentration enriched due to trypanosome infection. This was demonstrated in cattle and goats. Potential for use as biomarkers for trypanosomosis has been demonstrated.	Having a fly-proof experimental facility has been essential for this study.
To study the response of trypanosome positive biting flies to trypanosome induced semio-chemicals.	Semio-chemicals that are more attractive to trypanosome infected flies identified.	The trypanosome-induced volatiles have been identified. Evaluation of their attractiveness is on-going in the field.	The attractivity of urine from trypanosome-positive and trypanosome-negative animals evaluated in free flight assays showed that urine from infected animals was more attractive than the urine from healthy cow.	
To use trypanosome induced semio-chemicals for trypanosome diagnosis.	Biomarkers identified. Phenolic compounds, ketones and alcohols.	Biomarkers of animal trypanosomosis identified and their potential for use in diagnosis is being assessed.	The potential of phenolic compounds for trypanosomosis diagnosis tested on urine of sick and healthy cows.	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
Objective 2: To upscale and adapt tsetse repellent technology in partnership with the private sector and to reduce trypanosomosis risk by 50% by 2020				
Repellents for control of vectors of human sleeping sickness evaluated.	Synthetic and waterbuck repellent blend evaluated for *Glossina fuscipes fuscipes* in Kenya.	Evaluation of repellents against *Glossina fuscipes fuscipes* was completed. Blends shown to repel 30% of the species. Effectiveness of Waterbuck repellent blend demonstrated for *G. morsitans* and *G. m. centralis*	In collaboration with the Tsetse and Trypanosomiasis Control Unit (TTCU) of the Ministry of Livestock in Zambia, we are evaluating the repellent against southern tsetse species that transmit human and animal trypanosomiasis, *Glossina morsitans* and *G. m. centralis*, vectors of sleeping sickness, as part of scaling up the repellent technology in the southern region.	Need for extensive collaborative arrangements with tsetse control units of governments to enhance and extend evaluation of repellents.
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.	County government of Kwale purchased tsetse targets for deployment around the SHNR.	Repellent trap/target barrier demonstrated to reduce tsetse entry by 68%. Collaboration established for large scale evaluation of barrier around the Shimba Hills National Reserve (SHNR).	Need for collaboration with county government for sustainability.
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 commercialisation of tsetse repellent technology At least one local entrepreneur identified for manufacturing/ distribution of repellent collars.	Agreement completed with Innova biologicals for mass production and distribution of repellents.	Two repellent collar prototypes have been finalised as a result of R&D at icipe and the support of Gravalos in Spain and Celanese in Germany: a plastic (Fotron) and a fabric (canvas). Both dispensers are based on human-centred designs that eliminate challenges previously associated with handling liquid repellent formulations. The tsetse repellent on these is based on a solid matrix that is easily replaceable. Both collars will retail at less than \$5 (only 15% of original prototype) and refill at about \$1.5. A partnership has been established with Innova Biologicals Ltd, Kenya to mass produce and supply the repellent in the region. Innova has extensive networks that have	Need to adapt technologies to rural communities and associated informal settings.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
			engaged closely with the FAO to supply livestock vaccines and food supplements in Kenya and across the East African region.	
Business plan for commercialisation, packaging, product registration, marketing and dissemination for rollout of the technology developed.	Business plan developed for commercialisation, dissemination, registration and roll out.	Business platform for disseminating integrated tsetse control technologies developed.	Through a newly established partnership with mHealth Kenya Ltd, the action has developed an ICT platform that will be used by farmers, agrovets, animal health workers and the manufacturer to supply and track the use of the repellent technologies. The platform offers a sustainable job-creation business model with product vendors making small margins out of sales whilst scaling up the technology in hard to reach areas affordably. To ensure sustainability of the repellent technology and as part of exit strategy, six persons seconded to the action for training have now all been employed by the local government as regular staff. In addition, 60 community resource persons have been trained and engaged in tsetse and trypanosomiasis control. Through these, the local government's capacity for tsetse control and integrated use of tsetse repellents has been significantly enhanced.	Need for developing alternative distribution channels for tsetse control technologies because of a limited network of agrovets.
Advocacy of the repellent technology enhanced.	Advocacy of repellent technology enhanced in collaboration with stakeholders.		One PhD student, Joshua Njelembo has concluded his studies and resumed duty at the Tsetse and Trypanosomiasis Control Unit (TTCU) of the Ministry of Livestock in Zambia. Through Dr. Njelembo we have started a collaboration to evaluate the repellent against southern tsetse species that transmit human and animal trypanosomiasis, *Glossina*	Strengthening community engagement in project activities enhances awareness on the technology.

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons Learned during 2018
			morsitans and up scale the repellent technology in the southern region. Daniel Masiga presented progress on this action at the 17th AU-PATTEC Coordinators' meeting in Addis Ababa in November 2018. Seventy national AU-PATTEC coordinators attend the meeting, giving significant visibility to the action. 31 (25 men and 16 women) Community Owned Resource Persons were trained on the active monitoring and control animal trypanosomiasis, 31May – 1st June 2017; Muhaka Field station – Shimba hills; South Coast. 10 farmers (5 men and 5 women) were trained on the making and repair of NGU tsetse traps July 2017 – Shimba hill, South Coast by Kenya Tsetse and Trypanosomiasis Eradication Council KENTTEC in collaboration with icipe staff under the IBCARP Tsetse Component.	
Integrated validation trials in Shimba Hills up scaled 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 trypanosomiasis control in Kenya.		In Kenya, up scaling is ongoing in Majimboni, Lukore, Mangawani, Mwaluvanga and Mwaluphamba of Kubo division. After the introduction of the repellent collars and integrated use of traps in these locations, disease prevalence has reduced by >80% (Saini *et al*, 2017). As measured by anaemia (PCVs). Cattle are healthier, and drug use has been reduced by >50%. This exercise is being undertaken in partnership with local	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcomes*	*Lessons Learned during 2018*
			government and livestock keepers, Innova Biologicals and mHealth Kenya.	
Socio-economic impact of the repellent technology assessed.	Awareness created and socio-economic impact of the tsetse repellent products documented.			

3.3 Plant Health Theme: Progress Report as per RBM Framework Plan

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
Specific 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				
Biopesticide for thrips IPM developed and commercialized. Bean Flower thrips pheromone blend optimized. Thrips IPM strategies based on intercropping, use of biopesticides, semiochemicals and botanical pesticides developed.	Thrips and tospovirus management strategies for French bean, onions, tomato and grain legumes. encompassing at least two IPM components formulated by 2020.	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. No. of peer reviewed publications.	3 peer-reviewed publications: (1) Birithia et al 2018. Seasonal dynamics and alternate hosts of thrips transmitted Iris yellow spot virus in Kenya. African Crop Science Journal; (2) Muvea et al 2018. Endophytic colonization of onions induces resistance against viruliferous thrips and virus replication. Frontiers in Plant Science; (3) Douglas et al 2018. Evaluation of biorational insecticides and DNA barcoding as tools to improve insect pest management in lablab bean (*Lablab purpureus*) in Bangladesh. Journal of Asia-Pacific Entomology. Two post-docs study on-going for optimization of bean flower thrips pheromone in the lab and field. 4 abstracts were presented at the 34th Annual Meeting of the International Society of Chemical Ecology (ICSE) 2018, Budapest, Hungary.	
Field efficacy and use of Bean Flower thrips pheromone standardized. Field demonstration of thrips IPM strategies based on intercropping,	Awareness on thrips, tospovirus monitoring and management strategies created among agricultural extension officers/plant quarantine inspectors. French bean, tomato, onion	Awareness among at least 200 agricultural extension officers/plant quarantine inspectors enhanced on thrips and tospovirus monitoring/management by 2015.	Field efficacy of bean flower thrips pheromone evaluated in Mbita on cowpea and Mwea on French bean. Compatibility of bean flower thrips pheromone with entomopathogenic fungi (ICIPE 69) assessed in the lab.	

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
use of biopesticides, semiochemicals undertaken. IPM technology adapted and validated with grain legume farmers. *Ex-ante* and *ex-post* assessment of the introduced management strategies.	and grain legume farming enhanced by 2015.	Awareness among at least 1000 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. No. of training reports. Popular articles, mass media reports. No. of peer reviewed publications.	1 publication on bean flower thrips mating behaviour is under internal review. Publicaton; Niassy et al 2019. Characterization of male-produced aggregation pheromone of the bean flower thrips, *Megalurothrips sjostedti* (Thysanoptera: Thripidae), Journal of Chemical Ecology.	
Specific objective: Development of sustainable management strategies for insect vectors of maize lethal necrosis disease (MLND) in East Africa by 2018				
To identify and understand ecology of potential vectors responsible for transmission and spread of viruses causing MLN in East Africa To develop novel, effective and sustainable seed treatment strategies for the management of MLN To develop innovative and effective crop	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	Adults of corn leaf aphid, *Rhopalosiphum maidis* were found to be an effective vector of SCMV (Kinyungu et al 2018, World Journal of Agriculture). Interaction between vectors, host plants and viruses of MLND deciphered for the first time (Mwando et al 2018, Journal of Chemical Ecology). 2 MSc studies on tritrophic interaction and endophytes for resistance to MLN viruses and vectors have been completed.	

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
diversification strategies that influence both vector ecology and virus epidemiology.		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.		
Specific Objective: (Improved good agricultural practices and sustained food security) **African nightshade for capturing nematodes – using 'dead end trap crop' technology for tackling a new pest in East African potato production undertaken by 2019**				
PCN (potato cyst nematodes) characterized - Characterization 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.	More than 800 samples were collected in the main potato growing regions in Kenya. Molecular and morphological characterization of 182 samples have identified *Globodera rostochiensis* and, in 1 sample, *G. pallida*. A further 500 samples are currently being analyzed using barcoding molecular techniques to characterize the genotypic background of the Kenyan populations. Further characterization of the PCN populations are ongoing on a thermal	

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
			gradient table to assess hatching behavior at 12 different temperatures. This work is being conducted in close partnership with IITA and through an MSc student. A total of 31 live cultures of PCN have been established on potato or other Solanaceae such as African nightshade. The main species in culture is *Globodera rostochiensis*. The cultures are maintained at *icipe*'s campus in Nairobi. Molecular work was done to identify the H1 gene (resistance to *G. rostochiensis*) in some of the available Kenyan varieties showing for the first time that Shangi, the locally preferred variety, is susceptible to PCN. The 4 varieties showing *G. rostochiensis* resistance were Destiny, Markies, Jelly and Manitou. Further work is on-going to evaluate resistant varieties and PCN development in screenhouse pot-trials and an on-farm field trial.	
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.	To address the trap crop rotation strategy, we screened root exudates from 6 selected accessions of African nightshade and compared the PCN egg hatching activity among accessions and with potato and tomato. One accession of *S. scabrum* caused significantly high percentage hatching of eggs and is selected for further evaluation. In a field trial on PCN-infested land we evaluated the population dynamics of PCN in	

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
			two local African nightshade species (*Solanum scabrum* and *S. villosum*), African spinach (*Amaranthus dubius*), under fallow weed-free and in three potato varieties, including the locally preferred variety Shangi. In this 1.5-year field trial, results so far show an 80% reduction in the field population of PCN cysts after only 2 seasons under the African night shade crops. PCN was similarly reduced under the *Amaranthus* crop and fallow weed-free, indicating the natural decline of PCN under non-host crops is also high. At least 250 farmers have been sensitized to this trap crop rotation strategy.	
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.	6 African nightshade accessions were exposed to PCN infection in screen house experiments to evaluate whether infection of the roots occurred. All the tested African nightshade accessions did not support PCN development, confirming that indeed African nightshade are resistant to PCN infection. In these experiments the root exudates were collected and analysed to examine the presence of hatching factors and any novel or unique chemical components present. Preliminary liquid chromatography-mass spectroscopic analysis tentatively identified chaconine in potato and tomato exudates while solanine was identified in tomato, local *A. villosum* and in SSRV100561. Studies are underway to identify the unidentified	

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
			compounds.	
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.	7 biopesticides have been screened and tested in screen house trials for their effect on PCN. They include 3 isolates of *Trichoderma*, 2 isolates of *Purpureocillium lilacinum* and 2 commercially available biopesticides from Dudutech Ltd. Preliminary results indicate that all biopesticides have some suppressive effect on the reproduction of Kenyan *G. rostochiensis*. Amongst promising candidates is 1 *icipe Trichoderma* isolate and 2 from Kenya Biologics. In general, these isolates performed better than the commercially available biopesticides. Further trials are needed to evaluate the promising candidates under semi-field and field conditions; in conclusion, biopesticides for suppression of PCN is a realistic option in integrated management of PCN. In further bioprospecting activities, field collected PCN from the various sampling activities were examined for naturally occurring nematode-pathogenic fungi. In this work, fungi have been isolated from 21 different populations of PCN, that were successfully cultured for further identification and screening. Molecular identification has revealed the presence of 8 different fungal species including one *Pochonia* species known for its potential in biocontrol of nematodes.	
Farmers trained - Capacity building and technology transfer	Partnerships with NARS established.	Number of students trained/graduated.	Capacity building has been mainly in the form of student projects (11 BSc, MSc and PhD students). The students did particularly	The project was timely and highly relevant in terms of addressing a

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
initiated with national agricultural research partners and potato growers.	Joint stakeholder meetings conducted. Students trained and graduated. Farmers in main potato growing areas have obtained basic knowledge on PCN.	Number of meetings held. Number of farmers reached.	well, winning awards for best oral presentations. 6 peer-reviewed articles in scientific journals have been published. 16 training events were held in Kenya. 8 presentations were given at various international and local conferences and meetings/workshops. From the various sampling activities (output 1), it is estimated that at least 1,000 farmers have been reached and made aware of this invasive pest and its devastating effects. Locally, together with KALRO Potato Research Centre – Tigoni, joint training and sampling activities in the region has reached many end users and spread the knowledge on how to detect and tackle PCN in infested fields. For example, in an open day at KALRO Potato Research Centre-Tigoni, the number of farmers attending was over 250, comprising 59% men and 41% women. For capacity building, the research-extension linkage in a sister potato project being undertaken at KALRO Potato Research Centre-Tigoni was used; staff of *icipe* joined KALRO staff to teach a module on disease and pest management for 22 agricultural extension workers drawn from different	new pest in the region on a valuable food security crop, the potato. There was much motivation and energy to move forward to start tackling the planned outputs. The project also got a head start with a country wide PCN survey funded by FAO emergency funds conducted in 2016-2017. This work was led by *icipe* together with IITA, KALRO and KEPHIS. The survey revealed the country wide presence of PCN and paved the way for the characterization work of PCN in Kenya (output 1). The execution of the work plan was organized by delegating the activities to various members of the nematode platform team and involving interns (BSc students mainly) in the activities. The project results and activities are still ongoing and will continue to do so to

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
			areas. Through the establishment of farmer field schools after the training, each extension worker established two farmer groups with an average of 20 members directly reaching 440 farmers with practical training including management of potato cyst nematode. In collaboration with the GIZ project 'Promoting nutrition-sensitive potato value chains in East Africa', excellent PCN input was provided to the ToT activities. During this training, 27 trainers were trained on PCN management, who in turn trained ~2,000 farmers in Nyandarua.	come up with practical solutions for tackling PCN in the region. The inclusion of other important diseases such as bacterial wilt and interactions with above-ground pests must be addressed. The involvement of development partners was satisfactory and in future work could be improved by conducting more activities together, such as farmer field and business schools (FFBS). Currently, a working and active potato platform is lacking to bring all actors in potato production together to interact and address the various challenges the sector faces.
Specific Objective: Dissemination and Promotion of Mango Fruit Fly Integrated Pest Management (IPM) technologies by 2020				
Proven fruit fly IPM technologies disseminated and promoted among smallholder mango growers.	Establish partnerships with NARS, NGOs, private sectors, farmers and farmer groups relevant for the implementation of the fruit fly management activities. Assess the fruit fly	At least 5 partnerships established with national institutions and research partners relevant for implementation of fruit fly activities. The composition and abundance of damaging fruit fly species to mango	The project consortium is made up of Hawassa University (Ethiopia), KALRO (Kenya), EIAR (Ethiopia), Ministry of Agriculture and Natural Resources (MoANR) Ethiopia), Farmtrack Ltd, Technoserve (Kenya), Real IPM Ltd, Kenya Biologics Ltd, HottiServe East African Ltd, and Kibwezi Agro Ltd. Partners continued to implement	Partnerships have been crucial for the success of this project. Most activities in this result areas have been completed. More learning sites to be added and the impact need to be

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
	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.	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%.	research, dissemination and capacity building activities. In Kenya, mango samples were randomly collected from 20 learning sites and taken to *icipe* labs to generate the rate of suppression and infestation data. In Ethiopia, a consultant was hired from May-October 2018 to conduct studies on the distribution of fruit fly species in Ethiopia, particularly in Western, Northern and North Eastern Ethiopia where mangos are grown dominantly. Torula yeast and Cera trap are to be used with icipe 69. During the reporting period, the project has reached more than 10,000 growers through various dissemination pathways. Various fruit fly IPM technologies were distributed and promoted; these include traps and lures, food baits, biopesticides and augmentarium. Parasitoids were also released. In June 2018, a training for extension officers in Kitui County was held whereby 32 officers were involved in a fruit fly training. ASDE created a geo-referenced database (with appropriate GPS coordinates) of 998 mango growers who have been exposed to fruit fly IPM technology in the region. This data was used as a baseline. In Ethiopia, there are nearly 400 lead/model	documented.

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
			farmers and 4,500 farmers reached in 2018.	
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, colonization/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 two 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; At least one impact study of one parasitoid species	Import permits have been already processed, and during the reporting period, a total of 20,000 *F. arisanus* and *D. longicaudata* were shipped to Ethiopia to boost the already established laboratory colony in readiness for field release during the coming mango season (March-Aug). The interaction between exotic and local parasitoids is planned for the next reporting period. Two colonies, *F. arisanus* and *D. longicaudata*, established at *icipe* Ethiopia office with at about 20,000 wasps. In Kenya, parasitoid production has been boosted to 33,000 wasps. In Kenya where the mango fruits are currently in the season, the two parasitoid species (16,000 wasps) have been released in each of Machakos and Makueni counties. 17,000 of both species were released in Elegeyo Marakwet in Kenya. In Kenya, the parasitoids have established with an average parasitism level of 17% and spread at a radius of 8 km. While in Ethiopia parasitoid release are planned for the coming mango season.	More effort required to mass produce the parasitoid. The impact of mass releases in Kenya needs to be investigated.

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
		conducted on one cultivated and one wild fruit type in at least two project action sites.		
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 optimization 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 optimized for fruit fly monitoring and suppression in at least two project action sites. At least one host marking pheromone field tested and optimized 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 characterized 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.	The host marking pheromones (HMPs) of *C. cosyra*, *C. rosa* and *C. fasciventris* have been identified. Formulation and field validation studies are underway. The tests conducted showed that the materials are stable under field conditions and the starting doses were recovered even after 25 days. Oviposition substrates were treated with various HMPs (GSH, GA) and the derivatives (GSSG) at different concentrations and tested for fruit fly oviposition using *C. cosyra ovipositing* females. A similar experiment, testing only GA, was set up for *C. rosa* females. GSH significantly reduced oviposition in *C. cosyra* compared to the others in a dose-dependent manner. The same observation was made for the *C. rosa* experiment. 1 article published in the Journal of Agriculture and Food Chemistry. Fruitfly Mania is still being tested, and the product is going through the validation process for registration. Screening for bacterial symbionts in *B. dorsalis* adult flies has been conducted. Cultivable symbionts mainly Enterobacteriaceae and Streptococcaceae families were identified to associate with this pest. Experiments to test roles of these symbionts in development of the fly's life stages revealed that the	

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			interactions between multiple symbionts promoted development better than individual isolates and collectively better than when the fly was reared devoid of all isolates. Majority of the isolates did not alter the response of the flies to the commonly used biopesticide, *Metarhizium anisopliae*. However, one of the symbionts was found to significantly improve the performance of the biopesticide and more assays to demonstrate this are underway, as this could potentially be integrated into pest management. Discussions were done with the private sector partner Kibwezi Agro Limited (KAL) regarding the establishment of a hot water treatment plant at the Horticultural Crops Development Authority (HCDA). Experiment to determine the susceptibility of the fruit fly egg stage to heat treatment on Kent and Tommy Atkins mangoes are still ongoing. Similar discussions were held with a private sector partner, Sulma Foods Limited in Uganda, to establish a plant in Luwero, Uganda.	
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	Baseline on KAP related to mango production and IPM technologies developed in at least two project action sites. At least one *ex-ante* study	RCT was initiated in Elegeyo Marakwet for a robust analysis of the economic impact of the fruit fly IPM. Baseline survey involving 663 mango growing households was carried out in Dec 2017. The interviewed farmers were then classified into three groups (1) those	

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	including focus group discussions and household 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 up scaling on smallholder farms with data disaggregated by sex and age.	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. At least on *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.	that received trained only (225 households) (2) those that received training and received IPM materials (175) (3) control (223). A total of 289 fruit fly traps and 527- 400ml bottles of food baits were distributed to the 175 households based on the number of mango trees owned by each farmer, as reported during the baseline survey. *icipe's* entomologist team determined the number of traps and quantity of food bait and the corresponding number of trees. The IPM materials were given to farmers between Jan-Feb 2018. Two monitoring exercises were conducted; 4-8 June (31 farmers) and 27 June-21 July 2018 (418 farmers). The second monitoring also involved introducing phone-based reporting of mango data by the farmers to the researchers. Besides, larva and egg- infesting parasitoids were released during the second monitoring exercise. Descriptive analysis of the baseline data collected from Elegeyo Marakwet revealed mango to be an essential cash crop, contributing about 25% of all household incomes. About 48% of the farmers ranked fruit flies as the most important pest, with 27% of total mango losses attributed to the pest. The findings from Ethiopia reported during the last period were shared at the 10th International Symposium on Fruit Flies of Economic Importance, Tapachula, Chiapas,	

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			Mexico. A paper entitled "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" was developed from data obtained from Ethiopia and older IPM sites in Kenya (Embu, Meru and Machakos). The results of the paper show that the technology has a relatively high adoption rate and high prospects for adoption growth in Kenya compared to Ethiopia in the near future. An article synthesized from the ex-post data obtained from older IPM sites (Embu, Meru and Machakos- 500 mango producing households) titled "Do farmers and the environment benefit from adopting integrated pest management practices? Evidence from Kenya" was published in the Journal of Agricultural Economics. A follow-up household level survey in Elegeyo Marakwet, in Kenya, was conducted in October 2018. Sixty hundred and fourteen (93%) of those interviewed at baseline survey were revisited. The objective was to assess any change in mango production, harvest and fruit fly infestation, comparing those who received training and traps, training alone and control. The preliminary results from the follow-up survey showed a decrease in fruit fly infestation, but the difference was not	

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			significant across the three categories of farmers as classified for the RCT experiment (i.e. those that received fruit fly IPM training and traps, those that received training only, and the control group).	
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 pre-harvest management packages. Conduct Farmers' 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 pre-harvest 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 farmers' field days conducted in the project action sites. At least 60,000 fruit flies 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,	The 40 IPM learning sites were used for extension officers (74), ToT (79), CEP (20) and lead/model farmers (50). A group of 9 ADSE staff attended and participated in a ToT on IPM strategies of fruit fly; 31 more CESPs were also trained on mango fruit fly management; 32 Extension Officers from Kitui County were trained application of fruit fly IPM technology. 34 ToT courses on fruit fly taxonomy, monitoring, management and GAP were held for local officers. 105 learning sites. 8 field days. Starter packs were distributed. Mango farmers' field days focusing on mango fruit fly management were held at Malivani village and at Katulye village. Flyers: 5,000 Manuals: 500.	More learning sites and more extension officers training in mango growing areas of Kenya and Ethiopia.

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		farmers' magazines etc); At least one farmers' listening group formed in each project action sites; 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.	54 awareness campaigns IBCARP conducted awareness campaigns and demonstration activities reaching 1015 mango growers through field days and 515 through on-farm training. More training has led to adoption of the male annihilation to up to 24,838 traps. The IBCARP project ADS core group of fruit fly experts and CESPs have demonstrated the usefulness of augmentarium and availed starter materials to farmers, farmer groups and the farming community at IPM learning sites in Machakos, Kitui, Makueni; 3,680 farmers have been trained whereas 50 augmentoria has been availed; IBCARP through ADSE has distributed at least 3,000 copies of fruit fly fliers to growers during field days, on-farm training and workshops. Capacity building of 4 students continued at *icipe*. Two oral presentations and 5 posters on fruit fly work presented at the 10^{th} international Symposium of fruitfly of economic importance in Mexico. In Ethiopia, a 10-day training has been provided on mango fruit fly parasitoids rearing, and colony management to 9 senior technical staffs from Arbaminch Plant Health	

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			Clinic, Ministry of Agriculture Plant Protection, Quarantine and Regulatory Directorate and 2 PhD students from Hawassa University.	
Specific Objective: Develop IPM tools and strategies for major coffee pests in East Africa based on a better knowledge of their bioecology by 2020				
Thermal requirements characterization 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.	2 manuscripts reporting thermal requirements and temperature-based models of development for the coffee white stem borer, *Monochamus leuconotus* and the coffee berry borer, *Hypothenemus hampei* submitted to Journal of Insect Physiology and Bulletin of Entomological Research, respectively.	
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 coffee industry.	A paper with risk maps for *Antestiopsis thunbergii* on an elevation gradient published in PlosOne. A manuscript providing risk maps based on temperature, at world scale, for the coffee berry borer in preparation.	
Characterization of major coffee pest population dynamics in coffee farms and of agroecological factors impacting the dynamics.	Networks of smallholding coffee farms implemented for observation in different locations. Data sets for monthly monitoring of *Hypothenemus hampei*, *Monochamus leuconotus* and *Antestiopsis thunbergii* populations and damage in	Data sets available for modelling work. Models describing the impact of agroecological factors on major coffee pest dynamics published in scientific journals. Sets of IPM recommendations for shade management and other best	Data sets completed. Analysis and modelling work under progress by a PhD student.	

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	different locations of East Africa. Main agroecological factors characterized 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.	practices available for major coffee pests, targeting stakeholders of coffee industry.		
Identification and utilization of semiochemicals 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*.	Kairomones isolated and identified from green coffee berries (one paper in Chemoecology in 2017). Repellent volatiles isolated and identified from red coffee berries (one paper in Chemoecology in 2018). Alarm and aggregation pheromones isolated and identified from antestia bugs. Candidate volatiles tested in coffee at different doses and with different trap designs. One paper in preparation.	
Specific Objective: Screening entomopathogenic fungi screening against termites in cocoa agroforests				
Develop improved biopesticide formulation	At least one potent entomopathogenic fungus	Results integrated in PhD thesis as a chapter.	14 entomopathogenic fungal isolates from two genera, *Metarhizium* and *Beauveria* were	Need to use the potent isolate for artificial

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and application strategy for termites' management in cocoa agroforests.	identified and co-formulated with CO_2 against termites.	One manuscript under development.	screened. *M. brunneum* Cb15-III was the most potent and virulent isolate. Co-formulation of *M. brunneum* Cb15-III with CO_2 generating materials for the control of termites in cocoa agroforests is done by our German partner.	inoculation of cocoa seeds and seedlings for endophytic property establishment to confer systemic resistance against termites and mitigate any other avoidance of termites in future. Screening for endophytic property is therefore ongoing.
Specific 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				
Push–pull technology implemented by over 120,000 farm households, and indirectly benefit over 1.5 million 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.	Target surpassed: push-pull adopted and planted by 49,168 (23,601 male, 25,567 female) more farmers on 56,543 acres in 2018, bringing the cumulative number of direct adopters to 207,048 in Eastern and Central Africa. This translates to over 1,242,000 indirect beneficiaries having improved food sufficiency, nutrition and incomes. Over 207,000 farm households experienced more than double increase in cereal crop yields (61.9% increase in maize yields), experienced 5 times more fodder, milk (460 L/year from 263 L/year), increased soil fertility, and increased incomes (aggregate economic surplus at 14.4% adoption level is USD 73 million). 217,048 (123,717 male, 93,331 female)	The multi-functionality of Push-pull in controlling stemborers, fall armyworm (FAW), 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 FAW is a new driver of push-pull adoptions in sub-Saharan

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		Number of partnerships formed. Number of stakeholders trained.	farmers were directly reached through group trainings, *icipe* and partner extension staff, farmer teachers, field days, video, drama, cartoon book exchange visits and agricultural shows. 5 new partnerships were formed in Rwanda, Burundi, Zimbabwe, Senegal, Burkina Faso and Ghana for scaling up push-pull in those countries.	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 technology. Farmers in Africa traditionally practice mixed agriculture. Promoting the uptake of the technology requires 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

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				private sector players remains key in scaling up push-pull technology. Their involvement also enhances impacts of the technology on beneficiary livelihoods.
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.	Several Napier grass cultivars were exposed to stunt phytoplasma and tested using nPCR for tolerance against NSD. 3 NSD-resistant cultivars (Wanga, Phanice and Tundwe) identified as alternative fodder grasses remained resistant to NSD both on-station and in multi-location farmers' fields, and did not show any physical symptoms after 4 seasons. 7 partnerships were established with Send a Cow and 6 agricultural training centres who set up 1,331 multiplication sites in Siaya, Busia, Kakamega, Kisumu, Homabay and Kisii. 6,874 farmers (2,712 males and 4,162 females) and 135 partners from these sub-counties were specifically trained on NSD management. 1 peer-reviewed paper published on the qualitative distribution of *Candidatus phytoplasma oryzae* in roots, stems and leaves of napier Grass.	At least 3 NSD-resistant Napier cultivars had no signs of NSD phytoplasma after 4 cuttings. This result was confirmed on-farm. The selected 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. Integrated management approaches for NSD involves 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

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				phytoplasma on different parts of Napier grass, (4) back transmission of the NSD-causing bacteria phytoplasma by the pathogen vector *Maiestasbanda*, and (5) effects of Phytoplasma on vector development.
Stemborer and fall armyworm management approach developed by exploiting early herbivory traits and plant signaling.	Staple food sufficiency achieved by at least 20,000 farmers in western Kenya by 2020 though grain yield increases by 30%. Novel scientific knowledge on early herbivory and plant signalling generated and applied in crop protection by scientists, extension agents and policy makers by 2020.	Number of 'smart' maize varieties with early herbivory traits identified. Number of farmers adopting the use of 'smart' maize varieties. 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.	Indirect defence abilities of 6 'smart maize' cultivars (locally-adapted landraces, improved breeding lines and commercial varieties) to stemborer (*Chilopartellus)* 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. Attraction of parasitic wasps, *Cotesia sesamiae,* to odors of plants exposed to *C. partellus* eggs and pest parasitism levels were 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. A manuscript is under development on the genome wide association study of egg-inducible indirect defence in maize.	Our study results showed that the egg-induced indirect defence trait was widespread in landraces but rare in improved varieties. The GWAS study identified 24 SNPs strongly associated with the trait, some of which were adjacent to earlier reported candidate genes for maize insect resistance including brown-midrib, maize insect resistance and terpene synthases involved in plant defence role. A field trial on selected genotypes revealed statistically significant differences in stemborer parasitism levels between maize genotypes.
Fall armyworm	Scientific knowledge	Percentage change in FAW	The functionality of the climate-adapted	Preliminary studies show

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management approach developed by understanding the mechanism by which Push-pull controls the pest by 2020.	generated and included in integrated management of FAW in Africa by scientists, extension agents and policy makers by 2020.	infestation in push-pull cereal fields. Number of farmers adopting the use of Push-pull integrated FAW management approaches. Number of peer-reviewed publications on integrated management of FAW using Push-pull technology. Number of stakeholders trained on FAW control by using the Push-pull strategy.	push-pull was evaluated for the management of fall armyworm (*Spodopterafrugiperda* J E Smith) (FAW). Field observation, both biophysical and socio-economic data were collected on FAW distribution, 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 FAW were further investigated. All the 49,168 (23,601 male, 25,567 female) farmers who adopted push-pull integrated FAW management approaches. Over 200 stakeholders were trained on FAW control using the push-pull strategy. A peer-reviewed paper compared the performance of climate-smart push-pull and maize-legume intercropping for management of FAW, stemborers, and striga in Uganda.	that SOS chemicals e.g. nonatrine,(E)-ß-ocimene, α-terpinolene, β-caryophyllene and humulene produced by desmodium repel ovipositing females of FAW. Farmers who had adopted the technology in Kenya, Uganda, Tanzania, Ethiopia, Malawi and Rwanda observed effective control of fall armyworm in push-pull farms. 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. This confirms the findings of Midega et al (2018) and provides field-based evidence for benefits of push-pull technology for mitigating FAW in Africa.

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				Survey results on farmers' knowledge of FAW are being prepared for submission.
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.	The performance of 4 different *Desmodium* species i.e. 2 commercial species (D. *intortum* and D. *uncinatum*) and 2 species of Africa origin (D. *incanum* and D. *ramosissimum*) was tested in Kenya and Tanzania against *Striga* and other biotic constraints, and evaluated for pest, disease and drought tolerance. 49,168 new farmers (23,601 male, 25,567 female) adopted push-pull integrated *Striga* control methods, increasing both acreage (56,543 acres) under integrated *Striga* control methods. Under the climate-smart push-pull *Striga* infestation was reduced 18-fold, and concomitantly grain yields increased 2.5 times. 217,048 farmers (123,717 male, 93,331 female) were directly reached through group trainings, *icipe* and partner extension staff, farmer teachers, field days, video, drama, cartoon books, exchange visits and agricultural shows. Five new partnerships were formed in Rwanda, Burundi, Zimbabwe, Senegal, Burkina Faso and Ghana for scaling up push-pull in those countries. 36 joint partner field days were conducted, reaching an additional 8,366 new farmers.	The performance of earlier identified *Desmodium* spp., mainly D. *uncinatum* and D. *intortum*, (which had been shown to effectively control *Striga* and improve crop productivity) was compromised by extreme aridity, necessitating the identification and characterization of new plants possessing the required ecological chemistry to protect crops against *Striga*. The new African-adapted *Desmodium* spp., *D. incanum* and *D. ramosissimum* significantly suppressed *Striga* emergence by >90%, showing their root exudates were effective in suppressing *Striga* parasitism. Additionally, the species equally and effectively suppressed

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				Striga infestations in both on-station and on-farm trials.
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.	The potential of push-pull cropping system in management of maize ear rots and associated mycotoxins in maize was investigated. Maize and soil samples were analyzed for mycotoxigenic fungi; aflatoxin and fumonisin production potential of *Aspergillus flavus* and *Fusarium verticillioides* isolates from maize and soil was determined; and methanolic extracts from *Desmodium* roots were ested for in vitro antifungal activity against toxigenic isolates of *A. flavus* and F. *verticillioides*. Cropping system had a very high significant effect on ear rot incidence and severity. Incidence of ear rots was observed to be lower in push-pull (7.3%) than in maize monocrop (20.8%). Information on the effect of push-pull control on aflatoxin contamination was disseminated to 24,708 (10,130 male and 14,578 female) farmers. Among the farmers interviewed at least 6,934 (2,267 males 4,667 females) farmers observed effective control of aflatoxin in their push-pull farms, where aflatoxin contamination levels reduced to 7.3% of the maize crop (compared to 20.8% in maize monocrop). A paper was published in the African Journal	Maize ear rots and associated mycotoxins (aflatoxins and fumonisin) were significantly reduced in push-pull cropping systems. *Fusarium*, *Aspergillus* and *Acremonium* spp. were the most prevalent fungal genera in maize samples from both push-pull and non-push-pull cropping systems. The population of F. *verticillioides* and *A. flavus* was significantly lower in maize samples from push-pull, with all the samples from push-pull having aflatoxin levels below the Kenyan threshold (10 μg/kg).

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			of Agricultural Research, and another manuscript is under preparation.	
Specific Objective: Baseline information of plants - Lepidoptera stemborers – parasitoids interactions by 2020				
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.	1 PhD student is conducting his research in all projects in 2018. Bioassays (Y-tube experiments) and volatiles analyses by GC-MS achieved. Field surveys in maize fields 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 their associated parasitoids.	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). Appearance of *Spodoptera frugiperda* in Makutano first and later also in Murang'a. This allowed us to start a study on the interactions of this new invasive species with the already indigenous Lepidoptera stem borers.
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).	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	Identification of the type of intraspecific interaction that characterizes fall armyworm larvae resource utilization 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	Laboratory experiments done to study the interactions of S. frugiperda and stemborer larvae according to the temperature, the larval density and the duration of the interactions. *S. frugiperda* larvae acceptance tests by *Cotesia* species for parasitism initiated.	Availability of the studied insects.

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	during the non-cropping season as compared to surrounding wild habitat. 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 host acceptance by the stemborer's parasitoids, *Cotesia flavipes* and *C. sesamiae* towards *Spodoptera frugiperdae* larvae.	interactions under laboratory conditions. Identification of the effect of larval density and duration on the competition outcomes between lepidopteran maize stemborers community and the fall armyworm. Confirmation if *C. flavipes* and *C. sesamiae* are able or not to parasitize *S. frugiperda*.		
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. We identified unique gene families potentially related to metabolism of xenobiotic chemicals, pheromone biosynthesis, and immune response towards parasitism.	Genome sequencing and assembly done. Transcriptome sequencing and assembly done.	Importance of bioinformatic works in order to evaluate the assembly quality, to identify the repeat annotation, to identify functional annotation, to categorize gene ontology term, to analyze ortholog, to realize BLAST analyses and to identify horizontal gene transfer. This process

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				delayed planned publication.
Baseline information on host selection mechanisms by *Cotesia* spp. parasitoids (Braconidae) of Lepidoptera stemborers.	Identification of contract kairomone(s) involved in the host recognition and acceptance by *Cotesia* spp. parasitoids of Lepidoptera stemborers. Variability of the identified host kairomone(s) in host-parasitoid association. Determination of the candidate genes involved in host acceptance by *Cotesia sesamiae*.	Female parasitoids of *Cotesia flavipes* recognize their host and oviposit in reaction to an α-amylase, which is present in the oral secretions of the larvae of their host, *Chilo partellus*. Implication of α-amylase in the host acceptance and oviposition involved in different specific host-parasitoid associations.	1 PhD completed. 1 paper published in Journal of Chemical Ecology. 1 paper published in Frontiers of Ecology and Evolution. The study on the determination of the candidate genes involved in host acceptance by *C. sesamiae* ongoing.	For the study on the determination of the candidate genes involved in host acceptance by *Cotesia sesamiae,* production of both host and parasitoid was crucial and delayed planned study.
Specific Objective: Exploration for biological control of the invasive Guineagrass in USA by 2019				
Evaluation of the specialist stem borer of Guineagrass in Kenya, *Buakea kaeuae*, on the invasive Guineagrass of USA.	Field collections of *B. kaeuae* in 2 localities of Kenya on Guinea grass. Intensive rearing under *icipe* laboratory conditions on *B. fusca* diet.	First collection in the field of 349 of *B. kaueae* larvae. Second collection in the field of 120 *B. kaueae* larvae. Third collection in the field of 479 *B. kaueae* larvae. 441 larvae were reared up to the 4th generation under *icipe* laboratory conditions on *B. fusca* diet.		
Conduction of an Africa-wide collection of Guineagrass and analysis of DNA to determine molecular match between African Guineagrass and	Collections of Guinea grass from 16 countries in Sub-Saharan countries (South Africa, Botswana, Zimbabwe, Mozambique, Zambia, Cameroon,	Collections of Guinea grass from 5 African countries (South Africa, Botswana, Cameroon, Ghana and Tanzania) and all planned regions of Kenya.	Project achieved. AFLPs show South Africa is the match with Texas.	Importance of scientists networking (with confident colleagues) to be able to collect samples of Guineagrass all over sub-Saharan Africa.

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the invasive American Guineagrass.	Democratic Republic of Congo, Tanzania, Uganda, Ghana, Togo, Ivory Coast, Benin, Nigeria, Ethiopia and different regions of Kenya).			
Specific Objective: Integrated pest management strategy to counter the threat of invasive fall armyworm to food security in Eastern Africa (FAW-IPM) by 2022				
Establishing an emergency community based FAW monitoring, forecasting, early warning and management system (CBFAMFEW) in Eastern Africa.	Community-based FAW monitoring, forecasting and early warning established in target regions of Uganda, Burundi and Rwanda that aid in timely interventions for FAW management. Enhanced awareness on CBFAMFEW among policy makers, extension agencies and growers in Uganda, Burundi and Rwanda.	*Number of national/ county/sub-county FAW 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 FAW network in Uganda, Rwanda and Burundi.	409 national/county/sub-county FAW officers/staff/maize growers trained on monitoring and management of FAW in Rwanda (295 males and 114 females). 379 national/county/sub-county FAW officers/staff/maize growers trained on monitoring and management of FAW in Burundi (299 males and 80 females). 281 national/county/sub-county FAW officers/staff/maize growers trained on monitoring and management of FAW in Uganda (228 males and 53 females). 100 pheromone traps established in each target country.	
Regional preparedness, early warning, information on available management options and capacity for timely response to FAW infestation in Eastern Africa enhanced.	Extension agencies and maize growers in Kenya, Tanzania, Ethiopia, Rwanda and Uganda have access to FAW monitoring and surveillance tools. Additional effective FAW IPM options available.	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,	15 District officers, 20 Districts representatives and 200 people at village level, 350 NARS and District agronomists and 600 farmers in Uganda, Burundi and Rwanda were trained on monitoring and surveillance tools for FAW and their management in 2018. Effectiveness of one commercial biopesticide	

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	Best-bet cultural practices for FAW management promoted.	20,000 in Rwanda and 20,000 in Uganda have access to monitoring surveillance tools by 2022. By 2020, one additional effective FAW IPM option, registered and available for commercialization. At least 3 best-bet cultural practices identified and promoted by 2019.	(Met 789) for FAW established in laboratory and field studies. Label extension procedures on-going (Publication: Akutse et al 2019, Journal of Applied Entomology). Effectiveness of intercropping practices such as push-pull and maize legume intercropping for FAW management established (Midega et al 2018, Crop Protection; Khan et al 2018, Outlook in Pest Management; Hailu et al 2018, Agronomy Journal).	
An effective and sustainable IPM strategy to counter FAW in Eastern Africa developed for dissemination.	Sustainable and effective FAW IPM strategies available in Eastern Africa.	At least 3 effective and sustainable IPM strategies to counter FAW developed and disseminated for different agro-ecologies and countries by 2022.		
Knowledge on the biology and ecology of FAW enhanced.	Enhanced understanding on the biology of FAW in East Africa for development of FAW IPM strategies.	At least 3 publications highlighting FAW bio-ecology completed by 2021.	Diversity of FAW strains and their associated endosymbionts established in Kenya (Gichuhi et al, under review in Journal of Pest Science). Efficacy of various FAW pheromones molecules assessed in Aast Africa (Sisay et al, under review in Insects).	
Effective natural enemies for FAW identified, introduced, tested and released in target countries.	Both indigenous and introduced natural enemies of FAW 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.	Effective indigenous natural enemies for FAW control identified (Sisay et al 2018, Journal of Applied Entomology; Sisay et al, under review in Insects).	
Novel and environmentally friendly biocontrol technologies developed, tested and disseminated for FAW	Novel biopesticides and their application strategies available for FAW management in East Africa.	At least 2 biocontrol technologies developed by 2020. At least 25,000 growers in 3 target countries directly benefitting from	Laboratory screening of biopesticides for FAW management has resulted in the identification of more than 6 strains effective on egg, neonates and adult FAW (Akutse et al 2019, Journal of Applied Entomology, one	

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management.		biocontrol technologies by 2022.	under preparation).	
Habitat management strategies for FAW control optimized and scaled out to smallholder maize growers.	Habitat management and other cultural practices optimized and scaled out for FAW management in East Africa.	25,000 maize growers using FAW control push-pull by 2022.	Effectiveness of intercropping practices such as push-pull and maize legume intercropping for FAW management established (Midega et al 2018, Crop Protection; Khan et al 2018, Outlook in Pest Management; Hailu et al 2018, Agronomy Journal).	
Locally adapted FAW-resistant maize cultivars, hybrids and landraces in Africa identified.	FAW resistant maize cultivars available for maize growers.	At least 1 FAW resistant cultivar availed and disseminated in partnering countries.	Laboratory and greenhouse assays for assessing the indirect defenses of maize to FAW initiated.	
Implementation of IPM strategy to counter FAW infestation in Eastern Africa jointly with maize crop growers, private sector, NARS, NGOs and growers enhanced.	FAW 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 FAW-IPM technologies by 2021. At least 40% of the maize production area affected by FAW (341,262 ha) in the target project areas covered by at least 1 effective FAW-IPM option by 2022. At least 3 technology demonstrations in each country in each year. At least 1 TV program/Youtube video; one radio program and 1 news article per year developed and translated. At least 5,000	3 national ToTs, 15 District Meetings, ~50 Villages level trainings, 10 refresher grouped trainings in 2018. 15 District officers, 20 Districts representatives, 200 people at village level, 350 NARS and District agronomists and 600 farmers in Uganda, Burundi and Rwanda were trained on monitoring and surveillance tools for FAW and their management in 2018.	

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		booklets/posters/brochures on FAW developed, printed and distributed each year. At least one FAW microsite developed and maintained.		
Research capacity in Eastern Africa to develop and implement a sustainable IPM strategy for FAW enhanced.	Enhanced capacity for research among researchers and institutions for development and implementation of FAW 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 FAW research by 2022. At least one open day for policy makers and NARS partners in each year.	One MSc study on-going and two MSc studies completed. Recruitments for 5 PhD students ongoing. Recruitment of one post-doc and one scientist ongoing.	
Livelihood, environmental and gender impacts of FAW along the maize value chain in Eastern Africa determined and utilized for decision making.	Socio-economic, environmental and gender impacts of FAW management facilitate promotion of FAW IPM strategies.	At least 150 high-level stakeholders reached per country with FAW 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 FAW- IPM options.	One study on assessing the knowledge, perception and management strategies adopted by maize growers in Ethiopia and Kenya completed (Kumela et al 2018, International Journal of Pest Management). One socio-economic study on economic impacts of FAW completed in Ethiopia (Menale et al 2019, European Review of Agricultural Economics).	
Specific objective: Strengthening citrus production systems through the introduction of IPM measures for pests and diseases in Kenya and Tanzania by 2018				
The incidence, severity and distribution of Huanglongbing	Countrywide survey conducted and the incidence, severity and	Incidence, severity and spatio-temporal patterns of HLB established and geo-referenced maps	Assessment of various fitness parameters of *Candidatus Liberibacter africanus* (Claf)-infected and no-infected psyllid showed that, CLaf-	

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(HLB)/citrus greening determined; and pathogen–vector interaction assessed.	spatio-temporal patterns of distribution of HLB assessed using molecular tools by end of 2017. The role of HLB infection on ACP vector competence, fitness parameters and dispersal capability assessed by quantitative real-time PCR assays by end of 2017. Stochastic models developed to assess the patterns of spread of HLB disease by end of 2015. HLB disease distribution and potential implications on citrus industry on a regional scale assessed using Earth Observation tools by end of 2017.	of their distribution in the two countries made available by end of 2017. Role of HLB infection on ACP vector competence, fitness parameters (e.g. fecundity) and dispersal capability established using qRT-PCR by end of 2017. Stochastic model to assess the patterns of disease spread developed by end of 2015. Hyperspectral pattern of disease spread, and regional distribution established using remote sensing tools by end of 2017.	positive *T. erytreae* had significantly higher fecundity, and higher propensity for dispersal compared to CLaf-negative *T. erytreae*.	
Ecologically sustainable management methods for ACP and associated HLB disease, and FCM developed, tested and implemented.	Behavioural evidence for kairomonal and female-produced sex attractants and repellents in ACP studied and tools for monitoring and suppression developed by end of 2017. Potent fungal and viral-based biopesticides and natural products identified, tested and implemented for management	At least two kairomonal and female-produced sex attractants and/or repellents of ACP identified by end of 2016. Synthetic analogues of the identified semio-chemicals tested in wind tunnel and in field cages by end of 2017. At least two isolates of EPF identified and their efficacy tested against ACP and FCM, and one virus product	*Metarhizium anisopliae* (ICIPE 69) was found to be very potent against FCM with mortality of 94.23%, and also compatible with the commercially available (LastCall) attract of the pest. ACT-proof screenhouses have been established at coastal Kenya, at Muhaka, *icipe* station. The facility has been accredited by the Kenya Plant Health Inspectorate Services (KEPHIS) as suitable for production of clean nursery stock and	

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	of ACP and FCM by end of 2017. An efficient attract-and-kill product that can be used in combination with biopesticides for management of both pests identified by end of 2017. Citrus plant materials/root stock for HLB resistance screened by mid-2017 using a participatory on-farm approach ACP proof nurseries established in strategic locations for production of clean nursery stock and HLB free materials produced by mid-2017. Best-bet IPM technology for controlling ACP and FCM among citrus growers at selected project action sites implemented by 2017.	introduced, and field tested against FCM by end of 2018. An IPM measure that combines the use of one soft chemical and biopesticide tested for ACP by end of 2016. At least one attract-and-kill product introduced into one country, field tested in combination with biopesticide against FCM by end of 2017. At least 20 citrus genotypes screened for tolerance/resistance to HLB by mid-2017. At least two insect-proof nurseries established and 500 HLB-free clean stock, produced by mid-2018. Best-bet technologies based on rotational application of biopesticide and soft chemical and clean planting materials for ACP and HLB management, and biopesticides and attract- and-kill for FCM implemented by 2017.	produced HLB-free clean planting materials. At the national research institution, a second screen house of the same standard have been installed at KALRO, Matuga.	
Knowledge integration, capacity building, and technology transfer with national public and private sector partners and growers established.	Regular meetings/workshops focusing on trans-disciplinary knowledge integration and learning among partner institutions and stakeholders organised by end of 2016.	At least one workshop for knowledge integration and learning among partner institutions and stakeholders conducted in each country by end of 2016. At least one ToT workshop conducted in each of the target	4 ToTs were conducted. 145 quarantine/extension officers (with 32% female participation) in Kenya and Tanzania have been trained on detection, surveillance and identification of the pest.	

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	ToT workshops on citrus IPM conducted by end of 2017. Citrus IPM technology learning sites established field days conducted, extension materials produced and disseminated by end of 2017. Postgraduate training conducted by end of 2017.	countries by mid-2016; at least one technology learning site and one farmer field day conducted in each of the target countries by end of 2018. At least 3 PhD and 3 MSc students trained on bioecology and management of the target pests by 2018.	511 citrus growers (with 47% female participation) have been trained on scouting for and management of this pest. For a wider outreach, articles on the pest have been published using different media houses. Four of the recurred postgraduate students have completed their study and graduated.	
Specific Objective: Promotion of post-harvest disinfestation of key horticultural crops in Kenya and Uganda by 2021				
Post-harvest disinfestation treatment of thrips on French been and false codling moth on bell pepper established.	Quality of vegetables improved through implementation of post-harvest 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 post-harvest disinfestation trials against thrips on French beans validated by end of 2019.	A PhD student has been recruited in March 2019 to undertake this study.	None.
Proven post-harvest disinfestation treatment of mango and avocado against fruit flies validated.	Quality of fruits improved through implementation of post-harvest disinfestation treatment.	Large-scale trials on avocado (cold treatment) validated by end of 2018. Large-scale trials on mango (heat treatment) validated by end of	An MSc student has been recruited. Time required by different immature stages of *B. dorsalis* to develop in Tommy Atkins determined in Kenya and Uganda.	After losing thousands of mangoes due to anthracnose infection, there is a need to apply fungicides from

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		2018.		flowering stage until fruit bagging stage in selected farms to provide mangoes for hot water treatment experiments.
Awareness and capacity on the post-harvest treatment of the target crop pests among various stake holders, including policy makers enhanced.	Knowledge of the use of hot water dis-infestation treatment among the partner entrepreneurs enhanced.	At least two private entrepreneurs trained on post-harvest treatment technologies by end of 2018. At least 1000 growers trained on pre-harvest IPM measures of fruits and vegetables as a prerequisite for successful implementation of post-harvest 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 post-harvest 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 post-harvest disinfestation treatments by end of 2019. At least one PhD and one MSc student trained on various aspects of post-harvest disinfestation treatments by end of 2020.	2 private sector partners (1 in Kenya and 1 in Uganda) were trained on pre-harvest and postharvest technologies. A training-of-trainer (ToT) program was conducted in Kitui; 15 agricultural officers and farmers were trained. A ToT was conducted in Luwero District, Uganda (25 agricultural officers, technicians, a student, a pesticide company representative) were trained. 1 MSc student was recruited in Uganda. More than 300 farmers were trained on pre-harvest management of target pests. A new farmer group of 40 in was established in Bwaziba parish (Uganda). Policy makers such as KEPHIS and the Kenya Bureau of Standards (KEBS) have been engaged.	More awareness and training on pre-harvest management of target pests is required, as this is the first step in successful management of pests of exported commodities.

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Pilot post-harvest disinfestation treatment plant for fruits and vegetables established and operationalized.	Post-harvest dis-infestation treatment implemented by the partner entrepreneurs.	At least one post-harvest disinfestation plant established in the project countries by mid of 2019. At least one post-harvest disinfestation plant becomes operational by end 2019.	Miniature hot water treatment procured and installed at *icipe* to guide the design and functionality of the bigger machine for the private sector.	The miniature version has informed us on key points to be considered when fabricating the larger treatment machine for the private sector (e.g. power consumption of treatment plant, water requirements and insect proof treatment facility.
Certification, standards of fruit and vegetable post-harvest treatment established.	Rule and regulation governing the use of the post-harvest hot water dis-infestation treatment shared and harmonized among the partner entrepreneurs.	At least one harmonised protocol developed by end of 2019.	Awaits completion of output 4.	None.
Access to lucrative export markets regionally and international for the target commodities facilitated.	Zero infestation of the target crop by the target pest at points of export. Access to lucrative export market regionally and international for the target commodities regained.	At least two awareness campaigns among policy makers on the efficiency of the post-harvest disinfestation treatments conducted by end of 2019. The entrepreneurs are able to access at least one regional/international export markets by 2020.	Awaits completion of output 4.	None.
Specific Objective: To enhance productivity of avocado and cucurbits among smallholder growers in East Africa through integrated pest and pollinators management (IPPM)				
Avocado-cucurbit-production systems in diverse agro-ecologies characterized for the role of pollinators and insect pests, and associated extrinsic and intrinsic	Avocado-cucurbit-production systems in diverse agro-ecologies assessed.	Landscape dynamic for cucurbit-avocado production systems in 3 diverse agroecology characterized by 2019. Species composition and genetic diversity of insect pests and	Maps of landscape have been produced. Two areas in Kenya were identified (Murang'a and Makueni), which are major areas for large-scale. production of avocado and cucurbits, respectively.	Avocado and cucurbit are not intercropped in a large-scale production system in Kenya and Tanzania. Landscape dynamic is

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factors.		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 characterized by 2019.	In Tanzania, West Kilimanjaro and Lushoto were identified and selected as sites for implementing avocado and cucurbits IPPM activities, respectively. A library of gut symbionts for pollinators (*Apis mellifera*) of avocado has been established. Test for the effect of several bacterial species of the gust symbionts on the survival of the bees have been initiated. One postgraduate student has been recruited.	characterized based on normalized difference vegetation index (NDVI), which is land productivity proxy.
Potential for integrating pollination and IPM services assessed at landscape level.	Knowledge of integrating pollination and IPM of the target pests enhanced.	Pest management practices and floral biology in the target crops characterized by 2019. At least 4 existing (biopesticide, protein food bait, male attractants, sanitation) and 1 new IPM option for sustainable management of insect pests of cucurbits and avocado adapted for IPPM and implemented by 2019. The nature and magnitude of interactions between the pollinators and IPM practices documented by 2020. Impact of integrating pollination and IPM on key cucurbit and avocado pests and pollinators' health established by 2019.	None yet.	None.

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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.	None yet.	None.
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 KAP was undertaken in Murang'a and will be used to estimate adoption and impact of IPPM interventions at the end of the project lifespan.	None.
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	9 postgraduate students (3 PhD and 6 MSc) have been recruited (70% female) and are currently undertaking research on various aspects of the project activities.	None.

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		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 GIS/earth observation tools by end of 2020.		
Specific Objective: Enhance availability, access of potent biopesticides for small-holder growers for the integrated management of crop pests for food and nutritional security in Kenya, Uganda and Tanzania through innovative product development, commercialization and promotion by 2021				
Strengthen Public-private-partnerships (PPPs) for development, production and promotion of biopesticides in East Africa.	Public-private-partnerships (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 organized by first quarter of 2018. At least one market survey and SWOT reports accomplished by end of 2018.	1 project inception and 2 satellite meetings organized. Business opportunity workshop organized. Market surveys conducted and SWOT reports under preparation. MTAs under revision for approval.	
Develop improved biopesticide formulation and application strategies for enhanced efficacy of potent biopesticides products.	Innovative biopesticide products, their formulation and application strategies adopted by private sector for commercialization.	At least two innovative formulation and application strategies of biopesticide developed and communicated by mid-2019. Potent biopesticides for at least 2 new and emerging pests identified by end of 2019.	1 PhD student recruited (screening for effective biopesticides for whiteflies). 3 MSc studies initiated (identification of effective endophytes for pest and disease management in French beans; field efficacy of bio-pesticides for *Tuta absoluta* management, screening for effective Bt isolates against FAW ongoing). Potent bio-pesticide with ovicidal activity against FAW identified (Akutse et al 2019, Journal of Applied Entomology). 1 field efficacy trial for biopesticide on FAW	

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			completed.	
Optimize 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 operationalized by end of 2020. At least one industry scale pilot mass production facility for biopesticides established by mid 2020 with a private sector partner.	Training activities on small-scale bio-pesticide production planned and accomplished in 2019. Procurement of equipment for validation and training facility ongoing. Discussions with private sector partners on pilot mass production facility ongoing.	
Register and commercialize 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 commercialization by mid of 2019. Eco- and mammalian toxicity of at least two biopesticide products/formulations assessed accomplished by first quarter of 2020. At least 2 dossiers for product registration submitted to regulatory authorities by mid of 2020.	Label extension procedures for Metarhizium 78 and fast-track registration of a new product for FAW management with Metarhizium 7 ongoing with private sector partners.	
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, optimized and operationalized by at least two women/youth groups by end of 2019.	Partnership between Horttiserve and RealIPM strengthened for demonstration of bio-pesticide products. Training on small-scale production planned. Stakeholders from MAAIF (Uganda) engaged in the project activities.	

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		At least one sensitization 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.	1 PhD and 3 MSc students recruited.	
Specific 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				
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 targ 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 damage and behavior. At least 25% reduction in the	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.	Over 2,000 beneficiary farmers engaged in evaluation and adoption of the IPM technologies tested. Beneficiary farmers are not using pesticides except under some circumstances. Over 500 extension agents and 8 graduate students trained. The use of IPM technologies resulted in 25% yield loss.	Dissemination of effective IPM options needs strong collaboration between farmers, extension agents and researchers. Most farmers don't understand the environmental effects of chemical pesticides; there is a gap in awareness creation.

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	frequency of pesticide application. Six PhD/MSc students trained Over 800 farmers and extension agents trained by 2019 (200 a year for 2016, 2017, 2018 & 2019).			
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 prioritization 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 prioritized 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.	5 partners, 2 in Tanzania (Tanzania Agricultural Research Institute and Dakawa Research Center), 1 from Kenya (Kenya Agricultural Livestock Organization) and 2 from Ethiopia (Ethiopian Institute of Agricultural research and Ministry of Agriculture) were identified and were actively participating in the project implementation. A total of 6 pest problems identified including 2 in maize (stem borers, fall armyworms), 2 in rice (blight and stem borers) and 2 in chickpea (pod borers and wilts). Over 1,500 on farm trials were conducted in the 3 countries with over 200 farmers participating in the demos. Push-pull and cropping system for maize stem borers and *Striga*. Resistant varieties, bio-pesticides and spacing and fertilizer management for rice IPM. Botanicals, seed dressing, water drainage and reduced use of softer pesticides for chickpea	Farmers tend to use pesticides more than IPM options due to shortage of information regarding IPM practices among the farming communities.

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
			IPM. Percent crop loss abated is being conducted.	
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. Communication and data-network systems with partners by end of 2019.	Number of scientists/institutions engaged. Number of pests, diseases and weeds identified and prioritized. 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). Number of pests, diseases and weds diagnosed. Number of people accessing data.	A total of 12 institutions were identified, 4 from each country. A total of 6 pest problems were identified including 2 in maize (stem borers, fall armyworms), 2 in rice (blight and stem borers) and 2 in chickpea (pod borers and wilts). Pest diagnosis using mobile app such as WhatsApp and telegram were identified as a platform to share pest problems and information. Over 200 participants were identified to subscribe to the platform.	The key partners in pest diagnosis (including farmers and extension agents) do not have smartphones that are suitable to share pest and disease pictures; however, most farmers and extension agents do have featured phones.
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.	Communication strategy developed. Number of audiences addressed. Number of people aware of IPM practices. Number of people applying IPM practices. Number of targeted stakeholders	This outcome has been achieved. Over 50,000 farmers are aware of rice, maize and chickpea IPM in the 3 countries. Over 20 million people are aware of IPM through mainstream and electronic media. 1,647 farmers use IPM technologies. The project partnered with 11 stakeholders in the 3 counties, with the University of	It is instrumental to define the communication approaches of the project. It helps to offer information better and to play key roles in bridging the science-policy interface. IPM is now more popular in East African

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
	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.	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.	Minnesota (USA) and with the target beneficiaries. 3 leaflets, 1 manual (in local Ethiopian languages), 4 working papers, 2 proceedings, 200 promotional materials (100 mugs and caps) during the FAW workshop with the support of VT, 4 rollup banners, posters, 125 certificates, news and blog stories have been produced. All the promotional and project communication materials were disseminated. Many people have been accessing the web-interface, but the number of people accessing the web-interface and downloaded documents are not yet identified. Pest management, IPM packages and on-farm training on push-pull technology are among the trainings provided for the farmers and extension workers. 28 workshops, 37 trainings on pest management and 12 farmer field days were organized in the three countries.	countries. Stakeholders are better informed on IPM and major biotic factors, taking well-argued decisions on important policy questions. Apart from the promotional materials, blog stories, news updates and working paper impact stories (photo and video) were developed. The stories were run on the IPMIL portal and *icipe*'s website. Compilation, production and dissemination of communication and knowledge products is required to enhance uptake of the IPM technologies. We often see new audiences, which is a measure of success, indicating we are delivering exactly what they need.
Information and capacity	Identification of incentives	Number of institutions	Three institutions participated.	Target countries do not

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
building to reform and strengthen policies that influence integrated pest management provided.	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.	participated. Policy gaps identified. Internal rate of return. Net present value. Number of policy briefs. Number of policy workshops.	Policy gaps on importation and use of biocontrol agents were identified. Push-pull technology, for example, increases maize yield on average by 25%; a potential benefit of 6,753 Birr/year. The estimated gain per person is 72% of the 3,781 Birr/person national poverty line.	have a policy on IPM; policy makers lack knowledge of IPM.
Specific Objective: MUSA - Microbial Uptakes for Sustainable management of major banana pests and diseases evaluated by 2020				
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.	Two fungal microbials (sourced from the microbial collections at CABI and Stellenbosch University) are being tested as endophytes for their efficacy to manage plant-parasitic nematodes and weevils in bananas. From the microbial collections at *icipe*, 18 isolates have so far been selected and are currently under screening for their antagonistic efficacy against the banana weevils and nematodes. Furthermore, one fungal isolate was isolated from a banana weevil cadaver and cultured on solid media. This isolate is yet to be characterized.	None.
EBCAs host range assessment.	A number of selected EBCAs active against at	Number of EBCAs successful in control of at least 2 pests in	21 fungal isolates have been screened for their efficacy against the banana weevil under	None.

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
	least 2 pests in banana (Plant parasitic nematodes (PPN) and banana weevil (BW)).	banana.	in vitro conditions. Preliminary data indicates 3 fungal isolates as potential candidates for managing *C. sordidus*. 6 microbial isolates have so far been screened for their efficacy against *R. similis* under in vitro conditions.	
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.	This activity is ongoing.	None.
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.	None yet.	None.
Field integration of EBCA based IPM.	Field data for integration of EBCA (fungi) based IPM against PPN and BW.	Field trial data.	This activity is ongoing.	None.
Objective 2: Minimise the vulnerabilities of horticulture and staple crops to climate change-induced pest problems by at least 10% by 2020				
Specific Objective: To disseminate knowledge of climate change impacts on ecosystem services and food security in Eastern Afromontane Biodiversity Hotspots by 2018				
Complementing, encapsulating and concretizing the research results of the climate change project Phase I (CHIESA) and to make them adoptable and adaptable to specific user groups as well as to wider audiences.	Integration, synthesizing, and reporting of results from different WPs and within WPs from CHIESA by mid 2016. Integration of scientific capacity at institutional level built to achieve overall objective of climate change adaptation by end of 2016.	Effects of climate change on biodiversity and habitats disseminated- Species distribution maps for pest insects for maize, crucifers, avocado and coffee imparted.	The CHIESA project has ended. Outcomes have been reported previously.	None.

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
	Synthesized results targeting a supra-regional Eastern Africa Mountain Biodiversity Hotspot, which also increase knowledge on National level impacts with feed into ministerial policies by end 2017.			
Strengthening the capacities of relevant professional partner organizations to be able to further communicate research results and related technology to the end users.	Maintenance and utilization of the GeoNetwork platform and weather monitoring infrastructure by mid-2017. Strengthen capacity of providers of extension service by end of 2017. Improved access to appropriate and affordable technologies by mid-2017. Implementation of community adaptation plans, including linking with the existing government planning processes by end of 2018.	GIS platform established for sharing geospatial datasets among at least 25 East African stakeholder organisations regularly utilized. Number of participants at trainings that showcase the utility of geospatial products. Number of new local and regional products derived. Geospatial datasets in use. Number of community training events.	Decision support GIS system was developed and conceptualized. The Adaptation for Ecosystem Resilience in Africa (AFERIA) project continued to disseminate and communicate CHIESA research results. A number of trainings on the utility of geospatial tools were held.	Partners and stakeholder's IT capacity needs to be further improved.
Specific Objective: Adaptation for Ecosystem Resilience in Africa (AFERIA)-Maize component.				
Enhancement of the distribution and abundance of the parasitoids of maize Lepidoptera stem borers.	Releases of *Cotesia flavipes* and *C. sesamiae* (inland population) in Kenya (Taita Hills, Murang'a and Makutano) and in Tanzania	Number of parasitoids released in each target region. Number of farmers sensitized in each target region.	More than 500 adult parasitoids were released in each target region. More than 300 farmers were sensitized in each target region.	The number of parasitoids to release has to be increased in the target regions, particularly in Taita Hills and Moshi.

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
	(Moshi). Farmers sensitization on the use of the parasitoids to control the maize Lepidoptera stemborers and TOTs training (i.e. agricultural officers).	Number of Kenyan and Tanzanian agricultural officers trained.	Training of 7 Kenyan and 2 Tanzanian agricultural officers.	Important to assess thereafter the establishment of the parasitoids released. Important to avoid the use of pesticide by the farmers in the regions where the parasitoids have been released even if *Spodoptera frugiperda* (FAW) is invading these target regions.
Objective 5: To generate sustainable wealth creation for improved livelihood and poverty alleviation in rural areas, through green economy and SCP promotion in Africa				
Specific Objective 5.1. Implementing and achieving the triple certification scheme				
A trained operational structure (staff, organization, equipment) in charge of the project implementation; project database created; 21,000 contracts with farmers for GI, FT and ECO certification.	Mt Rwenzori coffee production chain is capacitated and empowered. An organized structure is created, which is suitably trained and equipped, and meant to remain operational after the termination of the project.	Training publication (factsheets, guidebooks) by September 2019. A practical handbook on triple certification scheme. GI book of requirements.	30 new jobs have been created. 2,056 farmers have been reached.	
Specific Objective 5.2. Creating and implementing a dynamic, interactive knowledge platform, supporting the project development				
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	It provides a powerful organization 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	Preliminary design of the farmer registration questionnaire has been undertaken. Background development and design of the data capturing tools have been designed. Initial quality characterization has been carried out. The structural setup for uploading the	

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcomes	Lessons learned during 2018
production traceability platform interface.		buyers).	necessary data information has been designed.	
Specific Objective 5.3. Generating conditions for sustainability; SCP promotion				
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.	36 recruited field staff comprised of 6 business managers, 30 internal control systems team with backstopping of NUCAFE secretariat staff (project manager, project officer, accountant, chief Agronomist, information technology officer, marketing manager and quality manager).	
IPM strategy for Mt Rwenzori coffee production; climate change impact assessment and 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.	The "green" performance of Mt Rwenzori CVC and number of SCP practices implemented are enhanced: waste production is reduced, inorganic chemical are banned.	Compendium on coffee pest and disease control measures in compliance with ECO certification. IPM and climate change adaptation strategy guidebook. Pamphlets, factsheets presenting the action. SWITCH regional conference compendium. Policy recommendations documents. Platform implementation.	Successfully setup with field operational team. Data loggers have been set up. In order to create enhanced visibility at national and regional levels, the activity action was launched at the different levels in June 2018 and August 2018, respectively. This has attracted and created awareness to 1,520 stakeholders in the coffee sub-sector. Activities have also been publicized in the print, radio and TV media including continuous project highlight on social media such as Twitter, Instagram, Linkedin, etc.	

3.4 Insects for Food, Feed and Other Uses Programme: Progress Report as per RBM Framework Plan

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
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.				
Pilot production and demonstration facilities established at *icipe* 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.	Pilot production facility and feed sources for rearing BSF that is culturally and environmentally acceptable in Kenya documented by end of 2017.	Threshold temperatures and thermal requirements of black soldier fly *Hermetia illucens*: Implications for mass production established. Published, Chia et al. 2018. PloS one. 13(11): e0206097. Effects of waste stream combinations from brewing industry on performance of Black Soldier Fly, *Hermetia illucens* (Diptera: Stratiomyidae). Published, Chia et al. 2018. PeerJ 6: e5885 DOI 10.7717/peerj.5885. Influence of temperature on selected life-history traits of black soldier fly (*Hermetia illucens*) reared on two common urban organic waste streams in Kenya. Published, Marwa et al. 2019. Animals. 9(79): doi:10.3390/ani9030079. Black soldier fly has been reared on 12 different combinations and 7 single waste streams commonly available in Kenya with crude protein and fat content levels ranging between 38.5–62.7% and 14.0 – 39.2%, respectively, largely depending on the substrate used. Through the up-scaling program roll-out, several black soldier fly rearing facilities have expanded from 4 x 4 m space with yields of up to < 200 kg/month to 20 x 9 m screen house set up to achieve productivity of 3 – 5 tons/month in attempt to meet the increasing demand of alternative protein supply in the region. Differential susceptibility of black soldier fly larvae to entomopathogenic fungi (EPF) *Beauveria bassiana* and *Metarhizium anisopliae* has been evaluated. Among the 14 isolates of EPF screened, *M. anisopliae* isolate ICIPE 32 was the most pathogenic followed by isolate ICIPE 69, while among the *B. bassiana isolates,* ICIPE 35 (cbb6)	BSF can be reared on many waste streams to produce high quality protein biomass. Several threats can affect colony maintenance of BSF. Mitigation strategies should be put in place to minimize the risk of colony collapse.

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
			was most pathogenic followed by ICIPE 35 (cbb15), ICIPE 620 and ICIPE 676. The mortality varied between 40 – 70 % considerably between the isolates. Manuscript in preparation. The pathogenicity of entomopathogenic nematodes (EPNs) on the black soldier fly larvae and prepupa across different temperature regimes has been established. Larval stages were more susceptible (10 - 80%) to EPNs isolates (Mw8A, Naivasha, Palm and Yatta) followed by the prepupa (10 – 55%). Manuscript in preparation. In total 785 (496 males and 289 women) farmers, young entrepreneurs, policymakers and scientists were trained on insect rearing for integration into animal feed. Out of the total trained, 35% (275 farmers) have established small-scale production units.	
Socio-economic surveys carried out on the use of insects for feed in poultry, fish and pig farming. 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 2017.	At least 500 small-scale farmers surveyed by end of 2017. Comparative costs of at least 1 insect-based feeds assessed by end 2017. Market demand and cost benefit analysis conducted for at least one insect-based feed by 2017.	Interview of 878 farmers revealed that vegetables and purchased floating pellets were the most common feed for fish, whereas for poultry, commercial mixed feeds and home-grown grains were most commonly used. Pig production largely depended on commercial feeds and household food waste. Manuscript in preparation. More 70% of the farmers were aware and willing to buy insect-based feeds as an alternative to conventional feeds with fishmeal and/or plant protein sources that are expensive. There also showed willingness to rear insects for sale to commercial feed manufacturers/processors. Manuscript in preparation. Furthermore, interview of 668 consumers (66.02% males and 33.98% females) revealed that >90% of the respondents were willing to buy and consume animal products reared on insect-based feeds. One MSc thesis submitted and defended. One manuscript under internal review.	Farmers are willing to accept insects as alternative protein ingredients in poultry, fish and pig feeds.
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	At least 10 awareness stakeholders meeting organized 5 radio spots realized.	During this period a total of 4 awareness campaigns and 24 farmer groups visits were organized to sensitize farmers on the potential of integrating insect in feeds for poultry, pig and fish.	Sensitization of farmers is very crucial in establishing insect-based enterprise.

Expected Outputs Expected	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcome	Lessons Learned during 2018
	and fish farm enterprises.	At least 30% of farmers attending awareness meetings consider insect as an alternative source of feed for poultry, pig and fish farm enterprises.	After the awareness campaigns, additional 214 young entrepreneurs (36.92% females and 63.08% males) have been trained in *icipe*. A total of 120, extension officers, model farmers, waste producers, private company partners, county policy makers have been trained from Uasin Gishu, Kakamega, Nyeri and Kiambu Counties, to ensure buy-in and ownership of the project. All the farmers who attended the workshops considered insects as alternative source of feed for poultry, pig and fish. With regards to farmer perception on the use of insect-based feed, > 90% of them are aware that insects can form a good source of feed. 4 media houses coverage (Citizen TV, NTV, Milele FM and KTN) full covered the events, which is regularly aired for wider outreach (https://www.youtube.com/watch?v=PrCz3fkF_HQ and https://www.youtube.com/watch?v=jSj8VQEaNeE). Events were put on the most popular and widely read newspaper in the country (Daily nations). Youtube video of the workshop were made for future training workshops (https://www.youtube.com/watch?v=cIRYoHuKzU4). Low cost investment on black soldier fly farming by youths in western Kenya featured article by Kameme TV: https://www.youtube.com/watch?v=UJuqqJZpdpg. **Popular articles published on Insects for feed:** "Black soldier fly larvae farming and the future of food in Kenya" In: Ecomumu 13th July 2018, https://ecomumkenya.wordpress.com/2018/07/13/black-soldier-fly-larvae-farming-and-the-future-of-food-in-kenya/.	The media plays a crucial role in the visibility of project activities.

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
			"Save money and Earn millions with this Insect Farming", In Thika town today, 17th Feb, 2018 https://www.thikatowntoday.co.ke/2018/02/save-money-and-earn-millions-with-this_17.html -. "Business of breeding black soldier flies" In: Daily Nation, April 27, 2018 https://www.nation.co.ke/business/seedsofgold/Why-I-am-rearing-insects/2301238-4533696-kla044/index.html -. "Farmer traps flies to make pig, poultry feeds" In. Business Daily, Africa, 19th March 2018 : https://www.businessdailyafrica.com/corporate/enterprise/Farmer-traps-flies-to-make-pig--poultry-feeds/4003126-4348556-3o2bs4z/index.html. "Producing nutritious animal feeds from black solder fly larvae" In Kenya Climate Innovation article 07th February 2018: https://www.kenyacic.org/news/producing-nutritious-animal-feeds-black-solder-fly-larvae	
Capacity of youth and women farmers (small-scale and commercial) in mass-production, harvesting and primary processing of BSF (Black Soldier Fly) protein built.	Youth and women farmers (small-scale and small commercial) engage in mass-production, harvesting and primary processing of BSF.	At least 10 youth and 10 women groups trained in mass-production, harvesting and primary processing of BSF protein. At least 30% of the group members produce, harvest and process BSF.	A total of 24 model farmers from 24 different groups trained who participated in the workshops were further trained in icipe on practical aspects related to BSF harvesting to processing of BSF proteins. All the 24 farmer groups (100%) are at the early stages of BSF production and are supplementing the diet of free-range chickens with BSF. A total of 8 workshops have been organized to training and promote insect farming as an alternative ingredient in poultry, pig and fish. A total of 53 farmer groups (22 youth and 31 women groups) have been trained and provided starter kits for BSF production and its effective processing through sun drying of their larvae. All the youth and women groups above have been linked to small-	

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
			scale feed millers (e.g. Treasure feed industries Ltd) for possible feed formulation So, far 8% of the 53 farmer groups have upscaled to sell insects to small-scale feed millers.	
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.	At least one formulation for insect-based feeds for poultry, pigs and fish established and tested. At least two commercial small-scale feed companies willing to take the nutritious insect-based feed formulation for mass production. At least 1 PhD and 2 MSc students conduct and complete an on-station trials of at least one formulation for insect-based feeds for poultry, pigs and fish established and tested.	Feed formulation for poultry and fish with inclusion of BSF larval have been established and tested with weaning and starter pigs. A total of 26 small scale feed manufacturers are willing to take up mass production and safe processing of insect-based feed for commercialization after the awareness campaigns across the different counties. Four (4) small-scale feed processor (Treasure Feeds Ltd., Macden Animal Feeds Ltd.; GAF Feeds Ltd and Josiche General Traders Ltd.) are using the protocol for fish, poultry and pig feed formulation. The effects of insect-based feed on African Catfish was assessed as MSc study. Substitution of fishmeal with 50 and 75% insect protein provided faster growth performance with higher carcass crude protein level. Thesis write up and manuscript preparation is ongoing. On-station trials on poultry (ISA Brown exotic layers) has been completed as a MSc study. Chicks, growers and layers fed on insect-based feeds had superior growth to those provided with conventional fishmeal commercial feeds. Field trials on grower and finisher pig stages has been completed by a PhD student. All pigs responded well to a dietary replacement of fish meal above 50% with BSFLM, resulting in high growth performance and carcass yield highlighting the potential for BSFLM to partially or completely replace fish meal in commercial pig finisher.	

Expected Outputs Expected	***Expected Outcomes***	***Performance Indicator of Outcome***	***Progress made in 2018 in Achieving the Expected Outcome***	***Lessons Learned during 2018***
Target insect frass used to compost organic fertilizer and tested on target crops.	Insect-based residue composted to fertilizer and tested on at least 3 crops.	At least 1 MSc studies on the effect of biofertilizer on crop growth and yield completed by month 36.	On-farm trails completed by a MSc student, 50:50 ratio of BSF residue compost and NPK (synthetic fertilizer) provided superior yield and quality of Kales, French beans and Tomatoes.	
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.	At least one feed formulation is tested free from microbial pathogens and toxins, and can be proposed for mass production. At least two commercial small-scale feed companies willing to take the safe insect-based feed formulation for mass production.	Feed formulations with BSF were tested and found free of aflatoxin, pesticide residues and heavy metals that could be of any risk to fish, poultry and pigs. Fresh samples of BSF collected from different on-farm rearing revealed pathogens such as *Escherichia coli*, *Salmonella typhi*, *Staphylococcus aureus*, *Providencia* sp., *Morganella morganii* and faecal coliforms. Postharvest handling measures have been established to sufficiently eliminate all possible bacteria and fungi contaminants rendering them safe for use in feeds. Twenty-six (26) small scale feed millers are willing to take up processed insect protein ingredient in their animal feed formulation, provided the volume of BSF is enough to boost their productivity.	
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.	At least one protocol and tool for production of safe insect-based feeds available. At least two small-scale feed processors use the protocol and tools for feed formulation.	Insect samples boiled at 84°C for 10 minutes and dried in oven at 120°C for 2 hours 30 minutes, resulted in safe insect protein-based products. The dried insect samples were ground into powder, for feed formulation. The postharvest handling revealed no pathogens (bacteria and fungi contaminants) of concern that might pose a negative impact on poultry, fish and pig production. All 30 different feed formulations using BSFL meal for pig, poultry and fish trials were found to be completely free from contaminants such as aflatoxin, pesticide residues, heavy metals and microbes. At least four (4) small-scale feed processor (Treasure Feeds Ltd., Macden Animal Feeds Ltd.; GAF Feeds Ltd. and Josiche General Traders Ltd.) already use the protocol for fish, poultry and pig feed formulation.	

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
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.	At least 10 youth groups and 10 women groups linked to profitable markets for insect-based feeds. At least 20% of the farmer group members are selling insects to small-scale feed processors.	A total of 53 farmer groups (youth and women) (100%) have been linked to small-scale feed millers (e.g. Treasure feed industries Ltd etc) for possible feed formulation. Activities on trainings on marketing and marketing access as well as linked farmers to profitable markets for insect-based feeds has been scheduled for 2019.	
Socio-economic assessment of community perception and livelihood effects on target insects completed.	Baseline survey on knowledge, attitude and practices and willingness to consume product derived from insect-based feeds established.	At least 4 target counties level surveys on community knowledge, attitude and practices with regards to the use of insects as ingredients in animal feed completed by month 24. At least 1 survey on consumer willingness to consume chicken meat derived from insect-based feeds completed by month 24. At least 1 MSc studies on socio-economics of edible insects completed by month 36.	Surveys in four counties (Kiambu, Nyeri, Kakamega and Uasin Gishu) as part of a MSc and Phd study revealed that >80% of fish and poultry farmers, >65% of pig farmers and >75% of feed traders and processors were willing to use insects as integral part of animal feeds. One manuscript under internal review for submission. An additional MSc study revealed that over 90% of the respondents show willingness to consume chicken meat derived from insect-based feeds. 1 MSc thesis has been completed awaiting graduation. One manuscript under internal review for submission.	
Objective: Develop and promote Insects for Green Economy (GREEiNSECT) by 2018				
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.	The distribution and diversity of crickets in 3 agro-ecological zones of Kenya has been established with a record of 18 potential species from six major cricket consumption areas in the Coast, Western and Central regions of Kenya. Magara et al. (2019), manuscript under internal review for submission. Among these samples, a new cricket species *Scapsipedus icipe* Hugel and Tanga has been described for the first time in Africa using integrated taxonomic tools, which include acoustic behaviour (call and courtship song), mitochondrial sequences, and morphological characterization. Published, Tanga et al. (2018). Zootaxa 4486 (3): 383–392. The growth performance of the newly described most dominant and widespread cricket on 6 diets of relevance for farming have been	

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
			established with the shortest development and highest survival rate on fed wheat bran diet. Published, Magara et al. (2019). 1–12. doi: 10.1093/jee/toy397. Female *S. icipe* fed on protein-rich diets (fish offal, soybean, and wheat bran) had significantly higher lifetime fecundity (> 1400 eggs) and fertility (> 80%), which is promising for its mass production Published, Magara et al. (2019). 1–12. doi: 10.1093/jee/toy397. The nutritional profile of the *Scapsipedus icipe* has been established. The pre-adult stages are highly nutrient-rich compared to the adults. The crude protein level of the adult is 62.5% and they are also rich in amino acids, fatty acid, flavonoids, minerals and vitamins. Mugane et al. manuscript draft under internal review. The thermotolerance and climatic suitability of edible cricket *Scapsipedus icipe* Hugel and Tanga (Orthoptera: Gryllidae) has been established. Magara et al (2019), manuscript ready for submission to Journal of Insect Physiology. The protocol for effective mass production of *Scapsipedus icipe,* and *Gryllus bimaculatus* and *Teleogryllus* (Teleogryllus) *pulchriceps* (Gerstaecker, 1869) has been established and colonies boosted to produce 220,000 – 425,000 crickets per week.	
The microbiological content of the key edible insects in Kenya (fresh, processed or stored form) identified and analysed. Molecular characterisation of microbial composition (DNA barcoding and/or RAPD) conducted.	Food safety and risk factors associated with edible insects documented. Information regarding the microbial composition of the edible insects improved.	The microbiological content of the key insects as food in Kenya identified by end of 2017. Molecular characterisation of microbes attacking edible insects and that pose a threat for food safety conducted by end of 2018.	The impact of processing methods on microbial load of reared and wild-caught edible crickets (*Scapsipedus icipe* and *Gryllus bimaculatus*) in Kenya has been established. Published, Jedida et al. (2019): JIFF-2018-004 (Accepted). Entomopathogens (including *Beauveria* spp., *Entomophthora* spp. *Metarhizium* spp., cricket paralysis virus (CrPV), microsporidia, nematodes, mites and the fungus *Aspergillus flavus* have been documented in laboratory colonies of crickets in *icipe.* Commonly observed bacteria included *Escherichia coli*, *Salmonella typhi, Staphylococcus aureus* has also been reported.	

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
Potential entomopathogens that pose a threat in the farming of insects profiled and documented.	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.	Differential susceptibility of the entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* as potential threat to *S. marginatus* and *G. bimaculatus* production has been established. Out of the 15-species screened Kapiti S3 was the most pathogenic *M. anisopliae* with mortality rates of 60 – 80%, while Caterp B recorded the highest mortality (70 – 90%) among the *B. bassiana* isolates. Tanga et al. (2019), manuscript in preparation. The percent mortality of cricket species (*S. icipe* and *G. bimaculatus*) to four species of entomopathognic nematodes (Mw8A, Naivasha, Palm and Yatta) regimes ranged between 22 – 78% across the different temperature regimes. Tanga et al. (2019), manuscript in preparation.	
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.	The partners of GREEiNSECT and EntoNUTRI jointly organized an International Conference on Legislation and Policy on the Use of Insects as Food and Feed in East Africa, with 105 participants from 13 countries. Post-harvest boiling at 96^{o}C for more than 5 min or toasting at 150^{o}C for 2 minutes was enough to eliminate all possible bacteria and fungi contaminants found in the processed insect. Impact of processing methods on microbial load of edible crickets in Africa has been established. Published, Jedida et al. (2019): JIFF-2018-004 (Accepted). Evaluation of fresh, processed and stored crickets showed no evidence of aflatoxins and pesticide residues as contaminants. Published, Jedida et al. (2019): JIFF-2018-004 (Accepted).	
Objective: Develop and promote insect feed for poultry and fish production in Kenya and Uganda (INSFEED I) by 2018				
Socio-economic surveys carried out on the use of insects for feed in poultry and fish farming.	Farmers and feed producers invest more in insect-based feed production and use	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.	A 16% higher Cost Benefit Ratio and 25% better Return on Investment was recorded when broilers were reared on black soldier fly (BSF) based feed compared to the conventional diet which was 19.0% more expensive.	

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
Market demand analysis for insects as feed ingredient for poultry and fish conducted. Economic performance of insect-based feed assessed.	and increase adoption by 2018.	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.	BSF were sold on the Kenyan market in 2017 between US$ 0.85-1.00. Preliminary BSF production costs are estimated at US$0.20.	
Rearing techniques for key insects suitable for use as feed developed and adapted. Wild harvesting techniques for swarming insects developed and adapted. Chemical and microbial contamination determined, and protocol developed for safe rearing and handling. Nutritive profile of key insects assessed. Insect based feed formulated and tested.	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. 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.	Bacteria identified from unprocessed wild crickets include *Erwinia spp, Enterobacteriaceae, Klebsiella oxytoca.* Fungal isolates from wild crickets include *Aspergillus spp* and *Penicillium roseopurpureum.* On reared crickets, Bacteria isolated include *Enterobacteriaceae, Enterobacter*, *Bacillus nealsonii.* Fungi isolated from reared crickets include *Aspergillus niger, Trichoderma asperellum,* and *Aspergillus flavus.* Deep frying, freeze drying, and snap freezing cleaned all bacterial and fungal contamination. 100% BSF based layer feed resulted in 62% higher egg production, 37.5% production cost reduction and longer egg laying time than conventional feed.	

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
		Effect of trap and post-harvest 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 utilization 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.	33% BSF based tilapia feed resulted in higher growth rate than conventional No difference in growth rate was found between conventionally and insect based fed broiler chicken. Dried BSF and cricket can achieve a shelf life of 7 months in form of powder. Substitution of fishmeal and soybean by BSF in feed increased potassium, magnesium and phosphorus levels but reduced iron and sodium levels. Pellet quality parameters remains the same between conventional and BSF based fish feeds.	

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
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.	A total of 3 stakeholder workshops were held in 2017. More than 500 farmers trained on insect farming. Standards for insect use in animal feed were approved in Kenya and Uganda in 2017. One story of change on gender outcome was published. Two papers published in peer reviewed journals in 2017: Mutungi et al. (2017) *Critical Reviews in Food Science and Nutrition*, doi: 10.1080/10408398.10402017.11365330 Ssepuuya et al. (2017) *Journal of Insects as Food and Feed* 3, 289-302 Six papers submitted to peer reviewed journals in 2017.	
Objective: Development and implementation of insect-based products to enhance food and nutritional security in sub-Saharan Africa (EntoNUTRI) by 2019				
Insect farming and harvesting techniques for edible saturniids, grasshoppers and crickets developed and production systems optimised using locally available substrates.	Edible insect-based technologies to enhance productivity and consumption of insects as food to improve livelihoods and wellbeing of rural and urban communities developed and disseminated by March 2019.	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.	Diversity of edible long-and short-horned grasshoppers in Kenya and Uganda established through molecular and morphological approaches. The long-horned grasshoppers were identified as *Ruspolia differens* present as green and brown colour forms, while key edible short-horned grasshoppers were *Acanthacris ruficornis* and *Crytacanthacris tatarica.* Through molecular analysis of the gut contents, 8, 3 and one host plants were identified for *A. ruficornis, C. tatarica* and *R. differens,* respectively. Interestingly fonio millet, *D. exilis* was the only host plant observed for *R. differens.* Leonard et al., manuscript under internal review).	

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
			Stable colonies of long- and short-horned grasshoppers established. Life table of *R. differens* at 20, 25, 30, 32 and 35°C have been completed. Rearing temperatures of 30°C was found to be optimal with low development time, low mortality and high fecundity. Cannibalism has been identified as a key factor hindering grasshopper rearing. Current assessments are focused on provision of insect proteins and visual barriers as a means to reduce cannibalism. Improved mass rearing protocols for *Schistocerca gregaria* and *Gryllus bimaculatus* using storable substrates such corn stover, soya extract, dried cowpea leaves and carrot powder were established. (Straub et al., Manuscript under review with Animal Feed Science and technology). Diversity and seasonality of edible saturniid caterpillars in east Africa assessed with molecular and morphological approaches. More than 7 species of edible saturniids have been identified. Three species of saturniids were identified in addition to the previously identified species. They include *Gonimbrasia ufipana, Gonimbrasia gueinzii* and *Gonimbrasia cocaulti* collected in Kwale, Nakuru and Taita/Makueni, respectively.A draft manuscript is under internal review. Egg and pupal diapause have been a major challenge in establishing a stable colony of saturniids. However, a stable colony of the shea butter caterpillar, *Cirina forda* which lacks diapause when fed on *Euclea divinorum* host plant has been established in Mbita. Key egg, larval and pupal parasitoids of saturniids that impacts on the population dynamics of saturniids has been identified and documented. A draft manuscript is under internal review.	

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
The nutritional attributes of target insect species (fresh, stored and processed) established and appropriate post-harvest technologies for preservation tested and implemented.		Nutritional attributes of at least 3 edible insects assessed by Dec 2018. Improved postharvest handling techniques for at least 2 edible insects developed by Dec 2018.	Nutritive profile of edible Saturniids and edible grasshoppers for various macronutrients such as Carbohydrates, lipids and proteins established. Assessment of limiting dietary mineral content in edible saturniids, grasshoppers and crickets revealed significantly higher levels of iron, zinc, calcium, copper, magnesium and selenium in all the edible insects. Significantly high levels of calcium and zinc were observed for crickets, followed by Saturniid caterpillars and *Ruspolia.* Analysis of deep fried on freeze dried samples of edible grasshoppers for selected carotenoids (Lutein, β-carotene and Zeaxanthin) were completed and Vitamins (Vitamin A and C) are on-going. High levels of Cryptoxanthin, Zeaxanthin, Riboflavin and β-carotene were observed in all edible insects as compared to conventional animal proteins. Deep frying was found to reduce the levels of essential vitamins.	
Food safety (chemical and microbiological) and regulatory requirements to inform policy on the use of insects as food established.		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.	The saturniid caterpillars stored under clean conditions were mostly free of harmful pathogens and aflatoxin producing fungus Microbial contamination of fresh and processed edible grasshoppers were assessed. Result indicated high levels of pathogens belonging to Enterobacteriaceae in insects sold by street vendors. Raw, wild harvested grasshoppers were processed on a laboratory scale by boiling for 10, 15 and 20 minutes and further by oven-drying and solar-drying. Boiling for 20 minutes sufficiently reduced the levels of *Enterobacteriaceae* and total viable counts to acceptable levels. Length of storage of the edible insects also significantly influenced the microbial contamination levels. High levels of lead and Iron contamination was observed in one of the wild harvested edible grasshoppers, which could be due to poor harvesting adopted. This is being further investigated.	

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
			Effect of packaging of processed edible grasshoppers in kraft paper bags with a viewing window on shelf-life is being currently assessed .	
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.		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 Dec 2018. Economic situation of edible insects' value chain actors assessed in 1 of the target countries by Sep 2018.	Survey in 15 counties in Kenya to establish community perceptions and practices regarding edible insects particularly concentrating on Saturniids completed and outcomes indicated that preference for edible insects is declining among the younger generation (A poster presented in Tropentag 2017 and manuscript is under internal review). A cross-sectional interview-based study was conducted among 74 edible grasshopper vendors from 12 major markets in Kampala and Masaka districts of Uganda to assess awareness among vendors on food safety issues. Results indicate extremely poor knowledge of post-harvest handling and poor personal hygiene practices stressing the need for training and education to effect behavioural change.	
Innovations on insect farming and utilization as food transferred to beneficiaries and R&D capacity and entrepreneurship in the field disseminated.		ToTs on insects to enhance food and nutritional security undertaken for at least 40 stakeholders (20 each for Kenya and Uganda) by Dec 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 Mar 2019. A project website established by Mar 2016. Advanced level training of at least 4 PhD and 5 MSc students, especially women, from Africa and Germany accomplished by Mar 2019.	ToTs on rearing, processing and utilization of edible grasshoppers among stakeholders in Kenya and Uganda are planned to be undertaken by mid-2019. Selection of participants for the same are on-going. One MSc study has been completed with one MSc study on-going. 3 PhD and one Post doc studies are on-going. Project students and scientist have participated in international conferences such as Tropentag 2018, IFW 2018 and 13th International Congress of Orthopterology 2019 and presented papers on various aspects of Insects for food and feed.	
Objective: INSect-based agriBIZiness for sustainable grasshopper and cricket production and processing for food in Kenya and Uganda (INSBIZ) by 2020				

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
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.	Treasure Industries Ltd in Kenya and Agrarian Systems Ltd in Uganda are engaged in the mass production of crickets and grasshoppers. Questionnaires have developed for data collection from harvesters, traders and consumers. The survey tools have been pre-tested and harmonized for use in Kenya and Uganda. Through a reconnaissance study in grasshopper hub areas of Masaka, Kampala and Fort portal in Uganda, it was observed that the central region of Uganda has the highest number of districts where grasshoppers are harvested (11) followed by the western region with 9 and lastly by the northern region with 2.	
Mass rearing protocols for crickets and grasshoppers adapted, piloted and upscaled.	Safe protocols for cricket and grasshopper rearing established 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.	Rearing facility for mass production of three major cricket species: *Scapsipedus icipe,* and *Gryllus bimaculatus* and *Teleogryllus* (Teleogryllus) *pulchriceps* (Gerstaecker, 1869) has been established and colonies boosted to produce 220,000 – 425,000 crickets per week. Mass rearing for "Senene" *Ruspolia differens* has been established in icipe. The mass rearing protocol for effective production of three major cricket species and grasshopper have been established for SMEs. High-quality nutrient-dense powder feeds (20% crude protein, 3000 Kcal/kg energy) for both crickets and grasshoppers have been established and shared with SMEs. Pathogens associated with the long-horned grasshopper *R. differens* has been established, which include *Aspergillus niger, A. flavus, A. tamari, Fusarium equiseti, F. solani,* and *Trichoderma koningii,*. The bacterium *Ricketsiella sp.* has been identified on crickets with characteristic pathogenicity symptoms which include swollen	

Expected Outputs Expected	***Expected Outcomes***	***Performance Indicator of Outcome***	***Progress made in 2018 in Achieving the Expected Outcome***	***Lessons Learned during 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.	abdomen, viscous yellow opaque hemolymph and partly dissolved body tissues. Bacterial isolates from the fresh wild and farmed crickets: *Enterobacteriaceae, Klebsiella oxytoca* and *Bacillus nealsonii.* Fungal isolates included, *Aspergillus sp*, *Penicillium roseopurpureum and Trichoderma asperellum.* The wild species had greater diversity of bacteria and fungi as compared to the cultured insects.	
Ready-to-eat whole insects, insect flours for use as ingredients in food preparation developed and characterized, and insect-enriched porridge flours and cookies processed.	Adoption and use of insect-based food standards in Kenya and Uganda and increased consumer confidence in insect-based products by 2020.	At least two food-based SMEs produce and commercialize insect-based food by 2019. At least two safely packaged insect products available on the market by 2019. Effect of various rearing and processing conditions on nutritional characteristics of crickets and grasshoppers documented by 2018. Insect-based products for women of reproductive age and five years old children or below developed and commercialized by 2019. Insect based novel food available on supermarket shelves by 2020.	Protocols for processing two ready-to-eat grasshopper products (a dry/shelf-stable and a fresh/chilled) have been developed. In collaboration with Nutreal limited, prototypes of cricket-enriched instant porridge flour and cookies rich in protein, energy, iron, zinc and vitamin A have been developed. Preliminary branding of the cricket-enriched foods as INSFOODS has been done. Packaging prototypes have been produced and would be evaluated for consumers' willingness to pay for the product.	
Favourable enabling environment for insect-based food through policy, advocacy and awareness creation established.	High consumer Acceptability for the insect-based products in Kenya and Uganda by	Policy briefs, advocacy and awareness creation materials established by 2019. Insect based food standards developed and approved in both countries by 2020.	Multi-stakeholder meetings involving researchers, partners policy makers and other stakeholders have been planned for 2019. Development of a webpage hosted by Makerere University website, to facilitate exchange of information and communication between INSBIZ team members and the public has been initiated.	

Expected Outputs Expected	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
	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.	Several media coverage registered: "Makerere University Starts Rearing Crickets And Grasshoppers For Sale" In DOBOZI April 2018: https://dobozi.com/index.php/news/business/643-makerere-university-starts-rearing-crickets-and-grasshoppers-for-sale. Makerere University to Start Rearing Grasshoppers: https://campusbee.ug/news/makerere-university-to-start-rearing-grasshoppers/. Ugandan research project hopes to make nutritious grasshoppers available year-round: https://www.pri.org/stories/2018-09-02/ugandan-research-project-hopes-make-nutritious-grasshoppers-available-year-round. Scientists to breed grasshoppers all year-round: https://www.monitor.co.ug/News/National/Scientists-breed-grasshoppers-all-year-round/688334-5007818-14v6fp7z/index.html. Radio Sapientia, 94.4 *FM*: Grasshoppers, crickets to be produced domestically: http://radiosapientia.com/news/grasshoppers-crickets-to-be-produced-domestically/. Makerere University to rear grasshoppers: https://www.youtube.com/watch?v=_w1xbRZeg3Y.	

3.5 Environmental Health Theme: Progress Report as per RBM Framework Plan

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
Objective 1: Survey, inventory, and description of new species of East African insects published and data made internet-accessible by 2020.				
At least 10 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 increased to 32.	Underestimated number of collaborating taxonomists. Change to 35 from 10 in the RBM.
At least 10 manuscripts produced by 2020 exclusively devoted to, or incorporating significant numbers of, East African insect taxa.	Taxonomists study and publish on East African insect taxa.	Number of manuscripts published on generic revisions, species descriptions, and regional checklists.	Number of peer-reviewed publications since 2014 now equals 30.	Underestimated number of peer-reviewed papers by collaborating taxonomists. Change to 35.
At least 30,000 specimens databased by 2020, matched to unique-specimen barcodes and made available on the Taxonomists and biogeographers access data base 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.	Database (ongoing) as of end 2018 includes approximately 10,000 entries.	Lack of adequate manpower to enter collection information and expert identifiers has kept the number of entries from increasing as much as we had hoped. Change to 15,000 from 30,000.
At least 10 taxonomists or biogeographers cite (via GBIF) ICIPE collection database in papers or reports by 2020.				Due to the constraint mentioned above, it is unlikely that the data will be accessed by 2020.
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 2018, 164 new species have been described and published in peer-reviewed journals. In addition, 23 more are in manuscript.	On track to reach our goal of 200+ new species described. Taxonomists usually have a lot of projects going simultaneously so that delays in completing manuscripts are occasionally encountered.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
Objective 2: Information on important pollinating Diptera (true flies) collected and made available on the internet.				
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 now stands at 2122; flower flies (1462), Pangoninae horseflies (124) and Bee flies (536).	
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.	Four field collection visits were made during 2018.	
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.	Venue changed in accordance with the wishes of donor (JRS Biodiversity fund) to increase presence outside of Kenya. Training to be held at Sokoine University in Morogoro Tanzania.	
Objective 3: Taxonomic information on African insects including major African pests and vectors used by scientists, students and public by 2020.				
10,000 DNA barcodes generated for the iBOL database.	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.	As of end 2018, 333,198 specimens were run, of which barcodes were generated for 17,460.	This result was better than expected based on earlier poor results for the Hymenoptera.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
		A taxonomic evaluation of poorly understood taxa, like stingless bees and African silkmoth species.		
Two trainings 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.	Number of students and staff members trained.	Number of training periods reduced to one per year.	Training periods were cut back due to excessive workload of PhD candidates.
African Insect Taxonomy Toolkit updated by 2015(http://taxonomy.icipe.org	Scientists and others make periodic use of taxonomic literature and tools.	External access rates are monitored.	Files for this site were lost as a result of a server crash, and they are not retrievable. Delete from RBM.	Backup data was not available.
At least four donor-funded projects with relevant taxonomic perspective request and receive taxonomic 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.	Demand for BSU services remains robust across ICIPE thematic units and projects. Monetizing these services should be facilitated by including both identification and photographic services as line items in projected project budgets.
Aquatic insects of streams in East Usambara area of Tanzania are identified and local groups are trained in their identification by 2020.	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 eight and 18 teachers participated.	This successful project was completed in 2018.
Objective 4: At least six 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				
At least four new potential products for mosquito control identified from plants based on efficacy, safety and ease of	Two plant-derived insecticidal products adopted for use in	Number of products produced and used.	Through efficacy and toxicity evaluation on target and non-target organisms (insects and mammals), and evaluation of its physico-chemical properties, the mosquito larvicide, *Uzimax*, has been shown to be effective, eco-friendly, biodegradable,	Prolonged bureaucratic product registration process are real when dealing with government agencies. The product

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcome	Lessons Learned during 2018
application. At least two plant-derived products for mosquito control formulated and packaged. Community-based cultivation of selected insecticidal plants initiated. Community-based production and use of plant-derived products for mosquito control initiated in at least one project site. At least two PhD and two MSc students trained. At least three papers prepared and submitted to international journals.	mosquito control by a local community by 2019. Three papers or patents on potential mosquito control products published by 2019.	Number of community members using the mosquito control products. Number of reports and publications. Number of students trained.	stable and safe for handling during application at the recommended and even higher dosages. A registration dossier was compiled which contained detailed data on efficacy, toxicity and physico-chemical properties of *Uzimax*, including its mode of action and application. It was submitted to the Pest Control Products Board (PCPB) of Kenya for registration. Following review of the dossier by PCPB, the dossier was approved for the second phase of the registration process. For the second phase, the project was issued with 3 test permits by PCPB to undertake independent evaluation of efficacy, toxicology, physical and chemical properties of Uzimax as a requirement before registration. The tests were undertaken by PCPB appointed institutions that included the following: Studies on physical and chemical properties of UZIMAX EC, to be undertaken by the Chemical and Industrial Consultancy Unit at the Department of Chemistry, University of Nairobi. Acute toxicity tests for UZIMAX EC including: Acute oral toxicity, acute dermal toxicity, eye irritation, acute inhalation, skin irritation and skin sensitization tests, undertaken by Department of Anatomy and Physiology, Faculty of Veterinary Medicine, University of Nairobi. Efficacy trials at semi-field and field level of Uzimax EC was undertaken by the Malaria Control Unit, Ministry of Health. Pest Control Products Board (PCPB) of Kenya approved summary dossier and independent testing reports combining toxicity, efficacy and physical chemical properties for *Uzimax*, and recommended issuance of a registration certificate. Water-soluble formulations of three additional insecticidal and medicinal plants named, *icipe*-MedPlant-21, *icipe*-MedPlant-31 and *NEEM OD 001* were developed that were effective as larvicides against larvae of 3 mosquito species, *An. gambiae*, *An. arabiensis* and *Cx. quifasciatus* in the laboratory and under semi-field conditions. The results indicated that the three additional	development plans to factor in time in future when planning to register a product to give clear estimate. More products should be developed from other plants for diversification and avoid relying on a single product.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
			larvicide formulations had potential for practical application in the control of mosquito larvae. Community-based cultivation of four insecticidal plants (O. kilimandscharicum. *Lippie javanica. Moringa stenopetala*, and *Ocimum ukambensis*) ongoing. Products 2,890 produced and used by the community Community members using the mosquito control products Approximately 2,330 people who bought and used the Naturub products that Improved their health and quality of life; The business community especially Chemists and Pharmacies made business from the sale of the products; Students Trained 4 Ph.D. students trained. 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: Mang'era, C. M., Hassanali, A., Khamis, F. M., Rono, M. K., Lwande, W., Mbogo, C., & Mireji, P. O. (2018). Growth-disrupting Murraya koenigii leaf extracts on *Anopheles gambiae* larvae and identification of associated candidate bioactive constituents. Acta Tropica. doi: 10.1016/j.actatropica.2018.12.009 Essoung, F. R. E., Chhabra, S. C., Mba'ning, B. M., Mohamed, S. A., Lwande, W., Lenta, B. N., Hassanali, A. (2018). Larvicidal activities of limonoids from Turraea	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
			abyssinica (Meliaceae) on Tuta absoluta (Meyrick). *Journal of Applied Entomology* 142(4), 397–405. doi:10.1111/jen.12485 Regina Ntabo *et al.* (2018) Enzymatic Activity of Endophytic Bacterial Isolates from Selected Mangrove Plants in Kenya. *The Open Microbiology Journal*, 2018, Volume 12 355. 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*). Reports: Enhancing the sustainability of community-based insecticidal and medicinal plant enterprises, biomonitoring of environmental health and youth sensitization in Kakamega, Kenya for livelihood improvement and biodiversity conservation. External end of project evaluation for the project 'DPE-005' Evaluator: Christopher N. Mutunga, Date of Submission: 5th August 2018 Enhancing the sustainability of community-based insecticidal and medicinal plant enterprises, bio-monitoring of environmental health and youth sensitization in Kenya and Tanzania for livelihood improvement and biodiversity conservation. Final Project report 2016–2018. A Descriptive Report Characterizing Households, knowledge of mosquito, malaria preventative measures and willingness to pay for UZIMAX bio-pesticide in Malindi, Kenya. Prepared by: Social-Sciences and Impact Assessment Unit, *icipe*, Nairobi	
Two plants with bioactivity against honeybee pests/diseases identified.	One plant-derived product for honeybee pests/diseases control	Number of products produced and used.	Report Apicure®, an essential oil-based biopesticide was evaluated for its role of olfaction in small hive beetle (SHB), *Aethina tumida*	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
One plant-derived product formulated and evaluated for control of a honeybee pest/disease. The bee pest/disease control product submitted for registration with relevant bodies. Protocols for production of the bee pest/disease control product established.	adopted for production and in use by 2020. Two publications/utility model/patent on potential honeybee pest control products published by 2020.	Number of reports and publications.	whose response showed that it has potential for the management of honey bee pests and diseases. The volatiles from Apicure® were collected using super Qadsorbent raps and subsequent analysis was done using Gaschromatography-mass spectrophotometry (GC-MS) to ascertain the components of Apicure®. GC-EAD analysis isolated 11 compounds that elicited antennal res ponse with the 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. A total of 18,000 pieces of *Apicure* biopesticide produced for validation in other African countries. **Publication:** Komen E, Murungi LKand Irungu J (2018).Behavioural response of the small hive beetle, *Aethina tumida* (Coleoptera: Nitidulidae) to volatiles of Apicure®, a 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 5: Geographic information systems are fully integrated as a strategic research tool for *icipe* by 2020.				
GIS and remote sensing training courses set up and given to students and resource managers.	*icipe* seen as an incubator for Earth Observation for insect science and ecology in Africa.	10 out of 12 ARPPIS students use a GIS derived map in their work in 2019. Number of peer reviewed papers on the use of GIS	Two trainings on GIS and remote sensing were given; one for ARPPIS and DRIP in Duduville Campus; and one Vectorbase workshop in Thomas Odhiambo Campus in Mbita. About 10 ARPPIS/DRIP students used their basic GIS and RS knowledge to produce maps showing their research results.	*icipe* is on the forefront of the use and application for crop disease and insect risk profiling and mapping in landscape scales in Africa, however, little uptake is currently occurring.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
		and remote sensing in insect science and climate change studies published.		*icipe* should link up with 'big data' processing and earth observation service and development partners (e.g., Remote Sensing Solutions (RSS), GmbH, in Munich, Germany) to develop wide-area surveillance, monitoring, and forecasting advisory service relevant to African agricultural productivity constraints.
Efforts undertaken to increase the use of GIS in new and existing projects.	Remote sensing and GIS are an integral part of the *icipe* working and research agenda.	A number of proposals and existing projects that make use of GIS and remote sensing.	More than five proposals that use GIS and remote sensing were developed. Also, most of the already existing projects either directly or indirectly used GIS and RS for mapping pests. Funding was secured for GIS work in an extended phase of the 'Biovision Foundation's push-pull scaling project' and 'BMZ strengthening citrus production systems through the introduction of IPM measures for pests and diseases in Kenya and Tanzania (SCIPM).	Funding efforts need to be more concerted towards large grants to enhance the number and capacity of personnel in GIS and RS. Effort should be put in place to strengthen the collaboration between the Geo-Information Unit and the already existing projects in other Themes/ Units.
Remote sensing (ecological) variables are derived and used for disease mapping.	Disease assessments are localised/more accurate so that interventions can be formulated with more precision.	A number of projects in *icipe* that use ecological variables derived using EO for improved assessments of pests and diseases, i.e. RVF, dengue, and malaria.	A number of vegetation phenological variables and climate data were used to accurately model and map insects, pests and disease risks.	Pest and disease risk modelling, profiling and mapping is a field that needs to be further enhanced; thus, more publications and staff development is needed. *icipe* needs to develop operational data processing routines to derive remote sensing ecological variables that can be related to pests and disease risk zones (hotspots).

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
Operational species diversity mapping framework developed.	*icipe* can use operational shared decision making (SDM) framework for enhanced decision making in IPM and as a marketing tool for funding.	A number of ecological and remote sensing models available and significantly understood.	Several ecological niche models for modelling and predicting the pest and disease risk zones were developed, but none of them have operationalized.	The GI Unit should develop a regional SDM-based crop pest as well as bee pest distribution models to precisely apply IPM technologies to control the pest.
Objective 6: Increasing honey and silk production by 20% in selected African farming communities by 2020.				
Potential and healthy silk and bee races identified for enterprise development in Africa by 2020.	Development of strains and identification of hybrids with productive merit	Initial data collected and more trials in progress for manuscript preparation.	Morphometrics and DNA barcoding of Eri and wild silkmoths first trials done. New Strains for *Bombxy mori* obtained from Rwanda and Japan in collaboration with Kenya National Sericulture.	Country policies may delay exchange of hybrid races.
Healthy silk and bee races are distributed to 3,000 trainers for the farmer groups.	60% of the farmers use improved bee and silk races.	YESH beneficiaries.	Five generic lines for *B. mori* and two generic lines for Eri silk for YESH beneficiaries. 65 boxes of four dfls produced, 23 boxes supplied to Uganda and four to Botswana.	Climatic condition may affect new strains performance. Figures are over-optimistic, should be reduced to 1,000.
At least 15 PhD and 10 MSc. Students trained.	n.a.	No. of thesis produced.	Four MSc students supported by the YESH project completed their thesis research. Six PhD undertaking their research project. One submitted for defense. Seven MSc undertaking their research, one submitted for defense.	Figures are over-optimistic for PhD, should be reduced to at least five.
At least 50 peer reviewed papers and five books/proceedings published in international journals.	n.a.	No. of manuscripts published.	13 peer reviewed papers and two papers in proceedings.	Numbers expected to be higher.
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).	A total of 92 ToT farmers (58 male and 34 female) were trained on the importance of beekeeping and climate change mitigation, Modern beekeeping using Langstroth hives and how to maintain standards for quality honey production, 30 Tots farmers were trained in Moshi (16 male, 14 female); 21	On Target

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
		Number of farmers applying their new knowledge.	Tots farmers trained in Muranga (16 male, five female) and 41 ToTs farmers trained in Taita Hills (26 male, 15 female). . Under the YESH Project a total of 5,202 youth (3,188 male and 2,114 female) have been trained in Entrepreneurship skill development and life skills; a total of 4,101 youth (2,692 male and 1,342 female) attended beekeeping technical skills development training another 1,115 youth (448 male and 667 female) have attended sericulture technical skills development training at project sites.	
Business model developed using value chain approach.	Business model and business responsibility adopted by at least 400 farmer groups.	Number of enterprises registered.	YESH project in progress to establish honey and silk youth enterprises.	Time factor to establish business enterprises.
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.	The YESH project supported the establishment of 4 honey and beeswax marketplaces; work has been underway for establishing two other marketplaces for sericulture.	There is a need to focus on the honey value chain and marketing of honey and others hive products.
Modern beehives supplied to farmers and rearing houses (silk moth) established.	500 beehives supplied to farmers by 2020. At least 100 rearing houses	Project records.	During the second half of 2018, the YESH project distributed 6,000 Langstroth frame hives and necessary hive tools. Also, over 6,000 bamboo and wooden silkworm rearing trays and mountages were distributed to project beneficiary youth in sericulture sites. A total of seven beekeeping demo plots using Langstroth hives have been established as follows: 30 modern hives for three beekeeping demo plots at Moshi in Tanzania. 20 modern hives for two beekeeping demo plots at Taita Hills in Kenya. 20 modern beekeeping demo plots for two modern beehives at Muranga in Kenya, 20 hives.	On target.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
Internal control system (ICS) training for 3000 trainers conducted.	Percentage of communities producing honey and silk to European Union (EU) standards increases from 20 to 30% by 2020.	Honey and silk quality assessed and certified.	30 Tots farmers were trained in Moshi (16 male, 14 female and 41 Tots farmers trained in Taita Hills (26 male, 15 female) on ICS.	Quality control not in cooperated in some projects.
Objective 7: Integrative Pollinator-Plant Interaction Assessment of Ecosystem Service Diversity in Sub-Saharan Africa (JRS Biodiversity Foundation Project) by the year 2020				
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.	Platform not developed and not in use.	Private partner for platform development stepped out of project, new partnership established.
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).	450 records collected.	
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.	450 records collected.	Common species to be identified.
Establish plant-pollinator networks for different land use types.	Deepened understanding of plant-pollinator interactions for conservation of pollination services.	Plant-pollinator networks.	Not yet started.	Networks to be established from field-based collections.
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.	Not yet started.	To be provided from field-collected samples.
Capacity building of stakeholders in database usage.	Increased uptake of database usage by other stakeholders.	Data records on interactions deployed.	Not yet started.	Dependent on database development.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
Capacity building for biodiversity bioinformatics for *icipe* staff.	Independent database development and management at *icipe*.	Number of staff to be trained in biodiversity databases.	Not yet started.	To be initiated when the 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				
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. 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.	The two value chain analysis reports produced – one on apiculture and another on sericulture – were finalised, validated and submitted to the Mastercard Foundation for further review. Both reports mapped main actors and the flows of products in the value chain. Baseline production levels quantified as part of the M&E framework. Bottlenecks in the value chains identified.	Both value chains are highly dynamic, and the reports will need to be updated after a few years.
The knowledge, capacity and technology-based	At least 8,750 youth capable to generate or	Identify, profile and select youth to form groups with a	By end of 2018, a total of 8,714 (30% female) YESH project beneficiary youth were selected, engaged and trained in	Some youth enterprises are engaged in other income

Expected Outputs	Expected Outcomes	Performance Indicator of Outcome	Progress made in 2018 in Achieving the Expected Outcome	Lessons Learned during 2018
entrepreneurship within the currently unemployed youth population increased.	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.	good balance in gender by 2019. Establish training and demonstration Centre's 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 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.	entrepreneurship and technical skills development. Of these, 6,838 are in apiculture and 1,876 in sericulture. Gender mainstreaming strategy document finalized, reviewed and submitted to the Mastercard Foundation for further review 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 was also used to provide practical training for 78 model youth silkworm farmers and 10 local sericulture extension staff. Nursery site development activities for the Year 3 group of youth have started during this quarter; seeds of 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.	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 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.	Provide training in assessing market information, improving marketing skills and analyzing market linkages in the value chain in the period 2016–2020.	By end of 2018 a total of 693 youth-led and owned enterprises were established from the Year 1, 2 & 3 cohorts of the YESH project beneficiaries, with 573 in apiculture sites and 120 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. Exploring alternative sources of credit is essential. The Mastercard

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
	At least 50% of youth engaged in beekeeping and silk farming able to access financial service by 2020.	Educate the young entrepreneurs in financial management and mediate in acquiring access to appropriate 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, which led the project team to explore alternative options for availing suitable credit services. Arrangements were made with local key institutions for availing business development services and mentoring. A total of 89 experienced local extension staff nominated to provide regular technical supervision to the youth enterprises have 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 30 model youth silkworm farmers attended resident practical training is sericulture including seed production at Bere Sericulture Production PLC. Practical bee colony multiplication on-site training was delivered to 151 model youth and 25 local extension staff and demonstrated as a line of business.	Foundation is also keen to see us consider and engage private microfinance institutions as well.
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.	Facilitate the establishment of legalized enterprises and cooperatives that are youth-led by early 2019.	By end of 2018, a total of 673 youth led enterprises established, 573 in apiculture sites and 120 in sericulture sites. Rehabilitation of four buildings to convert them into training and demonstration marketplaces has been completed during the second half of 2018. Work on two others will start in 2019.	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

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
	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.	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 benefit youth and their associations by end of 2020.	One of the two approved complementary project funded by EIF-WTO to support establishment of ten additional marketplaces has gone into implementation from November 2018 at apiculture sites. The one for sericulture was also approved but is awaiting complementary donor funding.	(crude honey, silkworm cocoons) through for instance complementary projects.
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 a M&E plan for the project including a detailed learning plan to ensure uptake of the technologies by 2017. 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	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 baseline surveys. Year 2 baseline survey report finalized at the end of 2018. Progress monitoring survey conducted on the Year 1 cohort of youth enterprises and the report prepared and discussed at various levels. Preparations finalized for independent midterm evaluation of the project.	The well set M&E framework and its implementation helped facilitate a more informative external midterm evaluation of progress of the project.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
		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.	Two consultants contracted to undertake the midterm evaluation report and conducted the field data collection at the end of 2018.	
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 a project website for use as a dissemination vehicle for the wider audience, including project activities, progress and results; project publications and presentations by 2016. 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	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, and immediately developed the project communication plan developed. To promote public awareness and create market linkages, two male and two female representatives of best performing youth enterprises were selected and participated in the World Bee Day celebration and honey festival in Mekelle; participants also visited similar successful youth beekeeping activities in Tigray Region.	

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		(internal and external) and enhance communication among all parties involved in the project by 2017.	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. Two project flyers (one for apiculture and another for sericulture) updated and translated into Amharic. Signages for training centres and project sites prepared; extension manuals and posters published and disseminated. Case studies initiated.	
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 2020.				
Assess of pollination efficiency of 10 stingless bee species and African honey bees in seven greenhouse crops in Kenya.	Pollination efficiency of seven stingless bee species and African honey bees assessed for seven horticulture crops in greenhouse in Kenya.	Fruits and seeds data records per tested crop species. At least one papers per crop prepared and submitted to international journals.	Pollination efficiency of seven stingless bee species and *Apis mellifera scutelata* conducted on Yellow bell pepper in green houses. Pollination efficiency of seven stingless bee species and *Apis mellifera scutellata* conducted on Cucumber in green houses.	Poor seed germination rate may delay planned experimental period. Stingless bees perform poor foraging activity under cold weather conditions. Need to set experiment during worm season and avoid June to middle-August period. Crop infestation by white fly and infestation by aphid if not treated at early stage may damage 70% of crops. Fast data recording in field and in Lab require a team of three people in minimum.
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.	Pollinator species diversity records per seasonal flowering periods. At least one paper prepared and submitted to international journals.	Pollinator species diversity recorded during the low flowering seasonal of October to December in Embu, Taita, Kirinyaga on two Macadamia varieties and two farming systems (Conventional and Organic). Average abundances of flowers per racemes recorded during the low flowering seasonal of October to December in Taita,	At least one-man power needed at each farm sampling site. For data to be collected efficiently there is need for the sampling operator to be based in the farm location.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
	One MSc student	One MSc student thesis on Macadamia pollinators in Kenya.	Embu, Kirinyaga on two varieties of Macadamia and two farming systems (Conventional and Organic). Average abundances of nuts per racemes recorded during the low flowering seasonal of October to December in Taita, Embu, Kirinyaga on two varieties of Macadamia and two farming systems (Conventional and Organic). One MSc student have registered at Kenyatta University. Introduction, materials and methods have been drafted for the manuscript in preparation.	
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.	GPS data of wild stingless bee nest had been collected in two provinces of DR Congo and additional province of Kenya. GPS data collected in previous years in Kenya, Madagascar, Zanzibar, Liberia, Ethiopia have been compiled. 277 stingless bee colonies of different species have been nested in wooden and clay pot hives for setting the stingless bee training centre. Site to establish the stingless bee training center had been identified in Kakamega forest. One MSc student from ULB in Belgium to conduct the species distribution model identified.	More sampling field work are needed in DR Congo and Cameroon. Need to incorporate samples from West Africa semi-arid countries. Need to relay on our own sampling effort in the field for efficient sample collection.
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.	Wing from stingless bee species sampled so far in Kenya, Zanzibar, Madagascar, Ethiopia, DR Congo have been mounted and analyzed using Morpho J. Stingless bee species samples collected from Kenya, Zanzibar, Madagascar, Ethiopia, DR Congo have been sequenced. Colored photos of individual live bees and nest structure of species occurring in Kenya have been taken for use in the African stingless bee book.	More sampling field work are needed in DR Congo and Cameroon. Need to incorporate samples from West Africa semi-arid countries.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Expected Outcome*	*Lessons Learned during 2018*
		Booklet on African stingless bees. At least one papers prepared and submitted to international journals.		
Capacity building of stakeholders in meliponiculture.	Training of at least one ToT from DR Congo, Kenya, Cameroon, Botswana and Ethiopia.	List of trained people.	Tots from Ethiopia, DR Congo, Kenya have been trained. Pilot rearing demonstration sites have been established in Ethiopia, Kenya, DR Congo and colonies nesting are ongoing.	High interest of stakeholders in meliponiculture. Training to be organized in their respective countries for high outreach and efficient technology transfer based on country specific occurring species.
Capacity building for pollination efficiency evaluation for *icipe* postdoc staff.	One *icipe* postdoc staff scaled up on pollination knowledge from a European Research Institution.	One post doc staff trained in pollination.	Request to attend short training on pollination was made to INRA Request to attend short training on pollination was made to Bio Best	June to July are the favorable climatic period; however, contacted scientist are not available during this season (holiday).
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.	One student had achieved a six months attachment on studying the pollination efficiency of seven stingless bee species and honey bees on greenhouse Cucumber crop.	Student attachment related to pollination efficiency study of bees on horticulture crop must cover six months period to cover information from crop nursery establishment to fruits/seeds data collection, recording and analysis.

3.6 Social Science and Impact Assessment Unit: Progress Report as per RBM Framework Plan

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Outcome*	*Lessons Learned during 2018*
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 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 successfully defended her thesis, awaiting graduation. One paper published "Githiomi C., Muriithi B., Irungu P., Mwungu C., Diiro G., Affognon Hippolyte A., Mburu J. & Sunday Ekesi S. Economic analysis of spillover effects of an integrated Pest Management (IPM) strategy for suppression of mango fruit fly Kenya. Food Policy Journal".	Adopting fruit fly IPM strategy for mango production, also impacts positively to other fruit fly host fruit crops especially pawpaw and citrus.
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.	One Msc thesis successfully defended and student graduated. One manuscript submitted and reviewed but rejected after submitting the first corrections.	Adoption of the fruit fly IPM strategy reduce health and environmental risks due to limited use of synthetic pesticides.
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 Msc thesis successfully defended and student graduated. One manuscript submitted for peer review "*Nyang'au P., Muriithi B., Nzuma J., Irungu P., Gichungi H., & Diiro G. Impact of integrated pest management strategy on food security among smallholders in Kenya*. Under review for African Journal of Food, Agriculture, Nutrition and Development (AJFAND)	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)

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Outcome*	*Lessons Learned during 2018*
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 At least one journal article produced by end of 2018	One draft thesis produced; student addressing corrections from the supervisors One manuscript submitted for peer review "*Gichungi, H., Muriithi B., Irungu P., Diiro G., & Busenei J. Impact of integrated pest management strategy on food security among smallholders in Kenya. Submitted to the European Journal of Development Research*	-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 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: 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 was produced "Willingness to Pay for Community-level Malaria vector control: An auction Experiment of Mosquito Larviciding using Biopesticides in Kenya"	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.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Outcome*	*Lessons Learned during 2018*
NAME of Project: Multi-Intervention Impact Assessment 4-H Project (H for Health) in Tolay (Ethiopia)				
Objective: 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).				
Sub-objective: 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 assessed and compared.	One impact assessment report utilised by donor by end of September 2014.	At least one (1) research report and one draft journal article produced by end of 2014.	Manuscript produced in 2017 was revised and improved: Menale Kassie, Samuel Ledermann, Gracious Diiro, Tadele Tefera, Shifa Ballo, Lulseged Belayhun. The economics of multiple interventions to achieve holistic outcomes: Pilot evidence from Ethiopia. Paper presented at the 30th International Conference of Agricultural Economists (ICAE) - held in Vancouver, British Columbia, July 28 - August 2, 2018.	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 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 cumulative impact achieved was 33 percent larger when the interventions are introduced jointly, suggesting synergetic benefits of interventions.
NAME of Project: Impact of biological control of stemborer on maize and sorghum production in East and Southern Africa				
Objective: To assess the impact of the BC programme on productivity, food security, poverty and environment at household level.				
Impact of the biological control programme on productivity, household welfare and environment assessed.	At least one (1) impact assessment report produced and shared with donors and partners by end of 2016.	At least one (1) impact study conducted by end of 2016. One scientific publication by end of 2016.	One PhD thesis produced, and student graduated in Aug 2018 One manuscript from this work published "*Midingoyi et al. 2016: Assessing the long-term welfare effects of the biological control of cereal stemborer pests in East and Southern Africa: Evidence from Kenya, Mozambique and Zambia. Agriculture, Ecosystems and Environment*"	Using economic surplus model, the study shows that that the biological control intervention contributed to positive and significant gains in all the three target countries. Further, the positive Net present value, internal rate of return and benefit-cost ratio) illustrated the efficiency of investment in the BC research and intervention. In addition, the BC-programme could lift out of poverty 57,400, 44,120 and 36,170 persons/year in Kenya, Mozambique and Zambia respectively.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Outcome*	*Lessons Learned during 2018*
NAME of Project: Integrated pest and pollinators management (IPPM) to enhance productivity of avocado and cucurbits among smallholder growers in East Africa				
Objective: 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 recruited in Kenya MSc proposal developed and reviewed by the students' supervisors	-
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	-Questionnaire for collection of baseline data developed	
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	Household-level survey tool developed Field design developed, and survey sites identified (12 wards in Murang'a county (classified in 3 agroecology classes (medium, high and low)).	Avocado-cucurbit systems are not common in avocado production areas
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 attitude and behavior regarding RVF among the study communities assessed and documented	Policy makers and partners have evidence on the impact of stakeholders training on their RVF knowledge and behavioural change regarding RVF	One Report on impact of community training on behaviour towards RVF	Follow-up data collected and analysis in progress	
NAME 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	Household-level survey involving 231 cattle keepers conducted in November 2018 in Merti in Isiolo County A report produced from the household data on "Knowledge, Attitude and practices of Rift valley	The results show that many farmers are not aware of the major risks associated RVF, leishmaniasis and brucellosis

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Outcome*	*Lessons Learned during 2018*
			Fever (RVF), Leishmaniasis and Brucellosis in Merti Sub-county, Isiolo, Kenya"	
NAME of Project: Youth Employment through Silk and Honey (YESH) Project in Ethiopia				
Livelihood contribution of framed beekeeping in rural Ethiopia	Project partners and stakeholder's aware role of framed beekeeping in enhancing livelihoods of farmers	One MSc thesis	One student (female) graduated	Results revealed that participation in farmed beekeeping significantly improves farm income. Empowering farmers through increasing access to information and skill training can enhance contribution of farmed beekeeping to improve rural livelihoods.
Impact of pollinator habitats and managed bee pollination on yields of pollinator dependent crops in Ethiopia	Project partners and stakeholders aware the importance of pollination services by bees and pollinator habitats to boost productivity.	One MSc thesis	One female student graduated	Value of pollinating dependent crops reduce as the crop plots are far away from forest resources. Number of managed bee colonies in a village significantly increases productivity of pollinated dependent crops in rural Ethiopia.
NAME of Project: Integrated Biological Control Applied Research Programme (IBCARP)				
Objective: Adoption and socio-economic impact assessment of fruit fly IPM				
Assess economic, human health and environmental impacts of combination of IPM techniques	Development partners aware economic, human and environmental health of IPM	At least one peer reviewed paper on impacts of combination of IPM	Manuscript published *"Midingoyi, Soul-kifouly G, Kassie, M., Muriithi, B., Diiro, G., & Ekesi, S. (2018). Do Farmers and the Environment Benefit from Adopting Integrated Pest Management Practices? Evidence from Kenya. Journal of Agricultural Economics"*	While IPM-adopting farmers have higher mango yields and mango net income, they also use lower quantities of insecticide and cause less damage to the environment and to human health. In addition, switching from one IPM to multiple IPM practices generates even higher economic, environmental and human health benefits.
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	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

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Outcome*	*Lessons Learned during 2018*
Adoption of Integrated Pest Management Strategy for Suppression of Mango Fruit flies East Africa): An ex ante and ex post analysis in Ethiopia and Kenya	Development partners and other stakeholders aware of farmer's adoption of IPM strategy	At least one peer reviewed paper	-One working paper produced	-Enhanced awareness/exposure can accelerate adoption of the IPM technologies among horticultural farmers in East Africa (using a case of Kenya and Ethiopia)
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)	-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 follow-up household survey involving 418 farmers interviewed in 2017 was conducted in July 2018. The second monitoring also involved introducing phone-based reporting of mango data by the farmers to the researchers.	-Phone-based reporting among smallholder is not feasible, chiefly constrained by the type/kind of phone gadgets used by the farmers.
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	-Household level survey involving 623 cattle keeping households conducted; and preliminary report produced and shared with the project team.	Preliminary results show that over 63% of the interviewed farmers are willing to pay for the icipe canvas collar and prototype dispenser.
NAME of Project: Core project: icipe technologies and gender impact and M&E strategy document				
Objective: Assess role of women's empowerment in agriculture and adoption of push-pull technology on farm- and aggregate- level impacts				
Evaluate effects of push-pull technology (PPT) in	Enhanced evidence on performance of PPT	Two papers on impacts of PPT	One working paper produced. Gracious M Diiro, Menale Kassie, Geoffrey Muricho, and Beatrice Murithi. 2018.	The results show that PPT adoption significantly reduces labor requirements during ploughing, weeding and threshing but

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving the Outcome*	*Lessons Learned during 2018*
Kenya and Uganda [labour. land policy paper]			The Effect of Technology Adoption on Intrahousehold Resource Allocations: A Case of Push-Pull Technology in Western Kenya	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 promoting wider up uptake of 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.
Understand role of gender in push-pull technology and other sustainable intensification (SI) technologies adoption	Policy makers, researchers and development partners use research results to enhance capacity and improve gender intervention in agriculture	Peer-reviewed paper on role of gender on PPT adoption and other SI technologies	Manuscript published "*Muriithi, B. W., Menale, K., Diiro, G., & Muricho, G. (2018). Does gender matter in the adoption of push-pull pest management and other sustainable agricultural practices? Evidence from Western Kenya. Food Security, 10(2), 253–272.*	-Push-pull is a gender-neutral agricultural practice, suggesting that promotion and dissemination of the PPT can be supported for enhanced food and nutritional security status of women and their households
Examine impact of women's empowerment on agricultural productivity	Policy makers, researchers and development partners use research results to enhance capacity and improve gender intervention in agriculture	Peer-reviewed paper on role of gender on PPT adoption and other SI technologies	Manuscript published: **Diiro, G.**, Seymour, G., Kassie, M., Muricho, G. and Muriithi, B. (2018) Women's empowerment in agriculture and agricultural productivity: Evidence from rural maize farmer households in western Kenya. PLoS ONE 13(5): e0197995. https://doi.org/10.1371/journal.pone.0197995	Utilizing plot level data, this paper provides evidence that women's empowerment contributes not only to reducing the gender gap in agricultural productivity, but also to improving, specifically, productivity from farms managed by women.
Assess women's empowerment impact on individual and household nutrition	Policy makers, researchers and development partners use research results to enhance capacity and improve gender intervention in agriculture	Working paper on women's empowerment on nutrition	Manuscript submitted (under review): Menale Kassie; Monica Fisher; Geoffrey Muricho; Gracious Diiro.: Women's Empowerment Boosts the Nutritional Gains from Agricultural Technology Adoption in Rural Kenya. Under review in World Development.	The results show that women's empowerment enhances the positive effects of PPT on women's and households' dietary diversity scores. The findings imply that individual and household welfare could be enhanced to a greater degree through interventions that promote women's empowerment and technology adoption simultaneously rather than separately.

3.7 Capacity Building and Institutional Development Programme: Progress Report as per RBM Framework Plan

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving Outcome*	*Lessons Learned during 2018*
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) complete their training in arthropod and related sciences.	At least 75% of PhD students who complete their training 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 (NARS), sub-Regional Organisations (SROs), International Research Centres (IRCs), and the private sector in Africa, each year during the period 2014–2020. At least 50% of MSc graduates trained at icipe continue a career in R&D or higher education, dealing with dealing with reducing poverty, improving food and nutritional security, improving human, animal and environmental health.	Number of PhD and MSc postgraduate students completing training with icipe each year during the period 2014–2020. % of women in the PhD and MSc programmes. Number of African nationalities represented by scholars in the PhD and MSc programmes. 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.* Number of graduates leading public & private organisations/ enterprises in Africa.	During 2018, icipe had 80 PhD fellows and 59 MSc fellows at various stages of their postgraduate programmes. In 2018, 45% of all postgraduate and postdoctoral fellows were women. In 2018, 16 African countries were represented by postgraduate students at icipe; *(Note: 7 new PhD scholars in the ARPPIS programme started in September 2018. With 6 African nationalities represented (Cameroon, Kenya, Nigeria, South Africa, Zambia, Zimbabwe) the new cohort represents significant country diversity entering the ARPPIS PhD programme.* In 2018, 14 PhD students completed training with icipe. Currently, 11 (78%) are now engaged in research, development and higher education in Africa; one (7%) is in research, development and higher education outside Africa; records are not currently available for two (15%). 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. This will be collected as part of routine alumni tracking from 2019. However, an ongoing tracer study of all alumni from the *icipe* ARPPIS PhD programme, dating back to	Although we implement on-going tracking of all alumni of the icipe postgraduate programmes, tracking of MSc students is difficult, especially those that pursue careers outside of research and higher education.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving Outcome*	*Lessons Learned during 2018*
			1983, indicates that approx. 70% of all alumni (from when the ARPPIS programme started in 1983 to date) are engaged in R&D or higher education in Africa; 6% are active in similar areas outside of Africa; and approx. 24% are not engaged in R&D, higher education or similar, or are untraceable, or are deceased. 15 MSc students completed their training in 2018. Eight (53%) are pursuing careers in research, development and higher education, including 2 doing PhD studies in Africa; 7 (47%) are currently unemployed. 145 postgraduate fellows who completed training at icipe since 1983 are in senior positions, contributing to R&D or Higher Education in Africa, although none of those who completed during the project period from 2014 are in senior positions.	
Dissemination of research results through 420 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	In 2018, of the 148 peer-reviewed papers published by *icipe*, 83 (56%) were authored by postgraduate students, (65 (44%) as lead authors). Citation metrics: Peer-reviewed publications by students had the following average number of citations and downloads for the years given: *Citations*: 5.75 (2014), 7.45 (2015), 3.7 (2016), 1.3 (2017), 15.87 (2018). *Downloads*: 50 (2014), 24.97 (2015), 42.7 (2016), 44.5 (2017), 79.38 (2018) 14 PhD and 15 MSc theses were completed in 2018. In 2018, 35 postgraduate students participated in 13 international/ regional scientific meetings &	Postgraduate students make a significant contribution to the research and publication output of *icipe*. To gauge the relative strength of first author student publications, we should include comparative analysis of publications first authored by icipe scientists, as well as those of students at other research centres and universities in Africa.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving Outcome*	*Lessons Learned during 2018*
		by the number of citations in peer-reviewed publications. Number of students participating in scientific meetings/conferences	conferences and 2 local scientific meetings & conferences.	
Mid-level practitioners and extension workers (200) from 30 national systems in Africa trained in non-degree professional development courses during the period to 2014 - 2020.	At least 50% of trained middle-level practitioners applying their knowledge and expertise in Africa each year during the period 2014–2020.	Number of training courses. Number of trainees. Number of new technologies produced and adopted. Training and information.	22 training courses 2,087 mid-level practitioners and extension workers trained in Push-Pull. 1,005 trained in other technologies (animal/human disease vector control; beekeeping and bee health; silk farming; plant health including Maize IPM, Fall army worm IPM, Coffee IPM, biosystematics and social sciences) 29 countries in Africa The number applying their knowledge and expertise in Africa is not known, although this information is currently being sought.	A routine plan for monitoring trainees after training should be incorporated into training programmes.
Undergraduate interns (150) trained during the period to 2016 - 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 insect and related sciences in 2018. Average duration of an internship was 3.3 months. Reports were received from all interns on completion of their internship. Tracking of interns immediately after attachment was not done.	The number of interns in R&D has increased dramatically from 28 in 2017 to 80 in 2018. The internship programme has become a significant component of the capacity building programme at icipe. Tracking of interns will be done from 2019.

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving Outcome*	*Lessons Learned during 2018*
Research and training capacities in insect and related sciences strengthened at national and regional research and higher education institutions through the development of an icipe Alumni Network. Institutions will include three ARPPIS sub-regional centres at Addis Ababa University, University of Ghana-Legon, University of Zimbabwe.	At least 5 new research or training programmes/ projects developed with national and regional partners each year during the period 2014–2020. Increased technology uptake and out-scaling in Africa 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	A collaborative training programme was initiated with Global One Health Initiative of Ohio State University for training of relevant stakeholders in East Africa in One Health. The project Combatting Arthropod Pests for Better Health, Food and Climate Resilience (CAP-Africa) was initiated in 2018 which included the training of MSc, PhD scholars and staff and students at partner institutions in Kenya, Uganda, Tanzania and Ethiopia. *icipe* was selected to become the Regional Coordination Unit for the Regional Scholarship and Innovation Fund (RSIF), the flagship project of PASET, for the building of doctoral and postdoctoral capacities at 10 selected universities in SSA in ASET fields. The development of the new icipe Alumni Programme is still under development.	The Capacity Building Unit at icipe does not currently have funds to support an full-time Alumni Network coordinator. Funds must be raised to support institutional development through an Alumni Network.
Career development opportunities for 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 new career development opportunities implemented 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.	12 postdoctoral fellows were engaged in research at various stages of their tenure at icipe in 2018. 5 postdoctoral fellows completed in 2017. All are currently employed, contributing to research, development and higher education in Africa. 32 peer-reviewed articles were published by postdoctoral fellows in 2018 (5 as lead author). In 2018, *icipe* postdoctoral fellows participated in 34 grant applications; 7 were awarded and signed, 7 approved - awaiting contract, 3 are under review and 17 were unsuccessful (= at least 40% success rate)	

Expected Outputs	***Expected Outcomes***	***Performance Indicator of Outcome***	***Progress made in 2018 in Achieving Outcome***	***Lessons Learned during 2018***
			In 2018 icipe was awarded one Future Leaders – African Independent Research (FLAIR) Fellowship. The successful fellow was competitively selected from more than 700 applicants for 30 fellowships (icipe had 13 submissions).	

3.8 BioInnovate Africa Programme: Progress Report as per RBM Framework Plan

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving Outcome*	*Lessons Learned during 2018*
Objective: 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	The following three (3) kinds of new knowledge has so far been generated by cohort 1 projects: Smart phone digital image analysis (i.e. using artificial intelligence) may help in field diagnosis of sweet potato varieties and diseases. The idea is being investigated in addition to biochemical means. Granulated fertilizer is a more effective and easier-to-use spherical product than pelletized cylindrical type. The supported team will explore the possibility to adopt granulation as opposed to palletization. It has been established that grasshoppers can feed on ground formulated feed. Grasshoppers are also omnivorous and can cannibalize each other in addition to eating other insects.	Continuous follow-up (virtual and physical) and support visits to project teams is necessary to align expectations of all partners. Capacity strengthening in product and business development remains a vital aspect of implementing innovation projects. Information management through technology increases efficiency and harmonizes communication among all stakeholders. An open, transparent and efficiently operated competitive innovation
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)	The following value-added products were developed by cohort 1 projects: 3 potent biopesticides (*icipe* 7, *icipe* 78, *icipe* 41) were formulated and were undergoing both lab and field testing. 24 demand-driven sweet potato varieties are identified for tissue culture vine multiplication at commercial scale (7 in Kenya, 5 in Rwanda, 6 in Tanzania and 6 in Uganda). Minimum Viable Products (MVP) of 2 ready-to-eat grasshopper products and cricket enriched instant porridge flour and cookies were developed and are being tested in the	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving Outcome*	*Lessons Learned during 2018*
			market. Approx. 500kg to 1 metric ton of MVPs of instant porridge flours and snacks from sorghum were tested in the market. 6 formulations of OKOA mushroom substrate blocks were made and are being tested in the market. Seeds of striga resistant maize varieties (Maseno 67D, Maseno EH 14, and Maseno EH 11) were undergoing multilocational trials in Kenya and Uganda. 25 research institutions and universities were selected as part of cohort 2 project teams collaborating with private firms.	grants funding model such as the one developed by BioInnovate Africa can be adopted for selecting innovation projects in the region.
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)	One (1) bioscience service i.e. integrated wastewater treatment is being piloted in the marketplace. Five (5) early-stage bioscience services are at different levels of development as follows: An early stage mobile application, Viazi Tamu is operational on Google App store and is being tested to promote commercialization of high quality and clean sweet potato planting material in Uganda, Kenya and Tanzania. An early stage protype of a Refractive Window Drier (RWD) has been locally fabricated to test drying processes of selected fruits in Uganda and Kenya. Minimum viable quantities of enzymes from bacterial isolates are being produced at University of Nairobi (UoN) to test dehairing of hides and skins at small-scale. A miniature hot water treatment tank has been installed at icipe to test post-harvest disinfestation of mangoes, French beans and bell pepper at small-scale.	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving Outcome*	*Lessons Learned during 2018*
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	A draft proposed structure for Maseno University Seed Unit business enterprise is in place. Preliminary value propositions have been documented for five (5) spin-off enterprises namely; Joraku Enterprises Ltd (Tanzania); Synamon Food Systems Ltd (Uganda); AMME Foods Plc (Ethiopia); OKOA Mushroom supplies Enterprises Ltd. (Tanzania); BioCon Company Ltd (Tanzania)	
Spin-off companies developed and supported	Increased linkages between research institutions and the private sector (agribusiness firms)	Number of company registration certificates	Three (3) company registration certificates are in place namely; Joraku Food enterprises (Tanzania), Synamon Foods System Ltd (Uganda) and Amme Foods Plc (Ethiopia) A founding team has been established for BioCon Company (Tanzania) An operating license was acquired for OKOA Mushroom Supplies Enterprises Ltd for Morogoro Municipality.	
Networks and partnerships developed	Increased linkages between research institutions and the private sector (agribusiness firms)	Increased linkages between research institutions and the private sector (agribusiness firms)	A draft license agreement between Maseno University Seed Unit enterprise and Agri Seed Co. was prepared. Three (3) sales contracts to supply wastewater treatment services have been concluded by BioCon Company Ltd. and clients in Tanzania. A draft Memorandum of Understanding (MoU) between INSBIZ Project at Makerere University and Masaka Microfinance and Development Cooperative Trust Limited was prepared (MAMEDICOT).	
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	Number of existing strategies/policies put by government that support and promote biosciences innovations	One (1) project was selected as part of cohort 2 teams to develop an innovation-led bioeconomy strategy for eastern Africa. One (1) policy seminar held in Dar es Salaam in collaboration with the Tanzania Commission for Science and Technology (COSTECH).	

Expected Outputs	*Expected Outcomes*	*Performance Indicator of Outcome*	*Progress made in 2018 in Achieving Outcome*	*Lessons Learned during 2018*
		Number of existing regulations put by government that support and promote biosciences innovations		
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)"	A framework for documenting BioInnovate Africa Alumni network was developed.	

SECTION 4: List of Refereed Journal Articles

Annex 1: January – December 2018 Publications List

2018 Published (151)

1. Agbodzavu K.M., Lagat Z.O., Gikungu M., *Rwomushana I.*, *Ekesi S.* and *Fiaboe K.K.M.* (2018) Performance of the newly identified endoparasitoid *Cotesia icipe* Fernandez-Triana & Fiaboe on *Spodoptera littorali*s (Boisduval). *Journal of Applied Entomology* 142, 646–653. https://doi.org/610.1111/jen.12514. S, IF 1.641

2. *Agbodzavu M.K.*, Gikungu M., Lagat Z.O., *Rwomushana I.*, *Ekesi S.* and *Fiaboe K.K.M.* (2018) Acceptability and suitability of *Spodoptera exigua* (Hübner) for *Cotesia icipe* Fernandez-Triana & Fiaboe on amaranth. *Journal of Applied Entomology* 142, 716–724. https://doi.org/10.1111/jen.12525. S, IF 1.641

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. (2018) 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*, doi: 10.1111/jen.12581. GOLD OA, IF 1.641

4. Aidoo Owusu F., *Tanga C. M.*, Paris T.M., Allan S.A., *Mohamed S.A.*, *Khamis F.M.*, Sétamou M., Borgemeister C. and *Ekesi S.* (2018) Size and shape analysis of *Trioza erytreae* Del Guercio (Hemiptera: Triozidae), a vector of citrus huanglongbing disease. *Pest Management Science* 75, 760–771. doi: 710.1002/ps.5176. S, IF 3.249

5. *Ajamma Y.U.*, *Onchuru T.O.*, *Ouso D.O.*, *Omondi D.*, *Masiga D.K.* and *Villinger J.* (2018) Vertical transmission of naturally occurring Bunyamwera and insect-specific flavivirus infections in mosquitoes from islands and mainland shores of Lakes Victoria and Baringo in Kenya. *PLOS Neglected Tropical Diseases* 12 (11), e0006949. https://doi.org/0006910.0001371/journal.pntd.0006949. GOLD OA, IF 4.367

6. *Ambele F.C.*, Bisseleua Daghela H.B., Babalola O.O. and *Ekesi S.* (2018) Soil-dwelling insect pests of tree crops in Sub-Saharan Africa, problems and management strategies—A review. *Journal of Applied Entomology* 142, 539–552. doi: 510.1111/jen.12511. S, IF 1.641

7. *Ambele F.C.*, Hervé B.D.B., *Ekesi S.*, *Akutse K. S.*, Djuideu C.T.C.L., Meupia M.J. and Babalola O.O. (2018) Consequences of shade management on the taxonomic patterns and functional diversity of termites (Blattodea: Termitidae) in cocoa agroforestry systems. *Ecology and Evolution* 8, 11582–11595. doi: 11510.11002/ece11583.14607. GOLD OA, IF 2.34

8. Aryal J.P., Jat M.L., Sapkota T.B., Khatri-Chhetri A., *Kassie M.*, Rahut D.B. and Maharjan S. (2018) Adoption of multiple climate-smart agricultural practices in the Gangetic plains of Bihar, India. *International Journal of Climate Change Strategies and Management* 10, 407–427. https://doi.org/410.1108/IJCCSM-1102-2017-0025. GOLD OA, IF 0.757

9. Azandémè Hounmalon G. Y., *Maniania N. K.*, *Niassy S.*, Fellous S., Kreiter S., *Delétré E.*, *Fiaboe K. K.* and *Martin T.* (2018) Performance of *Metarhizium anisopliae*-treated foam in combination with *Phytoseiulus longipes* Evans on *Tetranychus evansi* Baker & Pritchard (Acari: Tetranychidae). *Pest Management Science* 74, 2835–2841. http://dx.doi.org/2810.1002/ps.5073. S, IF 3.249

10. *Azrag A.G.A.*, Pirk C.W.W., Yusuf A.A., *Pinard F.*, *Niassy S.*, *Mosomtai G.* and *Babin R.* (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). *PLoS ONE* 13 (6), e0199569. https://doi.org/0199510.0191371/journal.pone.0199569. GOLD OA, IF 2.766

11. Badshah H., Ullah F., *Calatayud P.-A.*, Ullah H. and Ahmed B. (2018) Influence of the host plant on the encyrtid *Aenasius bambawalei*, a parasitoid used to control the cotton mealybug, *Phenacoccus solenopsis*, in Pakistan. *Pakistan Journal of Zoology* 50, 207–216. doi: http://dx.doi.org/210.17582/journal.pjz/12018.17550.17581.17207.17216. GREEN OA, IF 0.547

12. Bagny Beilhe L., Piou C., Tadu Z. and *Babin R.* (2018) Identifying ant–mirid spatial interactions to improve biological control in cacao-based agroforestry system. *Environmental Entomology* 47, 551–558. S, IF 1.661

13. Bama H.B., Dabire R.A., Ouattara D., *Niassy S.*, Ba M.N. and Dakouo D. (2018) Diapause disruption in *Cirina butyrospermi* Vuillet (Lepidoptera, Attacidae), the shea caterpillar, in Burkina Faso. *Journal of Insects as Food and Feed* 4, 239–245. GOLD OA, IF 0.00

14. Bamisile B.S., Dash C.K., *Akutse K. S.*, Keppanan R., Afolabi O.G., Hussain M., Qasim M. and Wang L. (2018) Prospects of endophytic fungal entomopathogens as biocontrol and plant growth promoting agents: An insight on how artificial inoculation methods affect endophytic colonization of host plants. *Microbiological Research* 217, 34–50. S, IF 2.777

15. Bamisile B.S., Dash C.K., *Akutse K.S.*, Keppanan R. and Wang L. (2018) Fungal endophytes: Beyond herbivore management. *Frontiers in Microbiology* 9, 544. doi: 510.3389/fmicb.2018.00544. GREEN OA, IF 4.076

16. Bayih T., *Tamiru A.* and Chimidessa M. (2018) Bioefficacy of unitary and binary botanical combinations against Mexican bean weevil, *Zabrotes subfasciatus* (Coleoptera: Chrysomelidae). *International Journal of Tropical Insect Science* 38, 205–215. doi:210.1017/S1742758418000036. S, IF 0.659

17. Beck J.J., Alborn H.T., Block A.K., Christensen S.A., Hunter C.T., Rering C.C. , Seidi-Adams I., Stuhl C.J., *Torto B.* and Tumlinson J.H. (2018) Interactions among plants, insects, and microbes: Elucidation of inter-organismal chemical communications in agricultural ecology. *Journal of Agricultural and Food Chemistry* 66, 6663–6674. doi: 6610.1021/acs.jafc.6668b01763. S, IF 3.412

18. *Bichang'a G.*, Da Lage J.-L., Capdevielle-Dulac C., Zivy M., Balliau T., *Sambai K.*, *Le Ru B.*, Kaiser L., Juma G., Maina E.N.M. and *Calatayud P.-A.* (2018) α-Amylase mediates host acceptance in the braconid parasitoid *Cotesia flavipes*. *Journal of Chemical Ecology* 44, 1030–1039. https://doi.org/1010.1007/s10886-10018-11002-10889. S, IF 2.419

19. *Bichang'a G.*, Da Lage J.-L., Sambai K., Mule S., *Le Ru B.*, Kaiser L., Juma G., Maina E. and *Calatayud P.-A.* (2018) Salivary α-amylase of stem borer hosts determines host recognition and acceptance for oviposition by *Cotesia* spp. (Hymenoptera, Braconidae). *Frontiers in Ecology and Evolution* 6, 228. doi: 210.3389/fevo.2018.00228. GOLD OA, IF 0.00

20. *Birithia R.K.*, *Subramanian S.*, Muthomi J. W. and Narla R. D. (2018) Seasonal dynamics and alternate hosts of thrips transmitted Iris yellow spot virus in Kenya. *African Crop Science Journal* 26, 365–376. OA, IF 0.00

21. *Bobadoye B.O.*, *Fombong A.T.*, *Kiatoko N.*, *Raina S.*, Teal P.E.A., *Salifu D.* and *Torto B.* (2018) Behavioral responses of the small hive beetle, *Aethina tumida*, to odors of three meliponine bee species and honey bees, *Apis mellifera scutellata*. *Entomologia Experimentalis et Applicata* 166, 528–534. doi: 510.1111/eea.12700. S, IF 1.454

22. *Bobadoye B.O.*, *Torto B.*, *Fombong A.*, Zou Y., Adlbauer K., Hanks L.M. and Millar J.G. (2018) Evidence of aggregation–sex pheromone use by longhorned beetles (Coleoptera: Cerambycidae) species native to Africa. *Environmental Entomology* 48, 189–192. doi: 110.1093/ee/nvy1164. GREEN OA, IF 1.661

23. Boff S.V., Friedel A., Miertsch A., Quezada-Euán J.J.G., Paxton R.J. and *Lattorff H.M.G.* (2018) A scientific note of housekeeping genes for the primitively eusocial bee *Euglossa viridissima* Friese (Apidae: Euglossini). *Sociobiology* 65, 766–769. GOLD OA, IF 0.604

24. Buffington M.L., *Copeland R.S.* and Van Noort S. (2018) Revision of *Afroserphus* Masner (Hymenoptera: Proctotrupidae) with the description of two new species. *Proceedings of the Entomological Society of Washington* 120, 687–707. S, IF 0.619

25. *Cham D.T.*, *Fombong A.*, Ndegwa P.N., Irungu L., *Nguku E.* and *Raina S.* (2018) *Megaselia scalaris* (Diptera: Phoridae), an opportunist parasitoid of honey bees in Cameroon. *African Entomology* 26, 254–258. http://www.bioone.org/doi/full/210.4001/4003.4026.0254. S, IF 0.508

26. Chang-Jun K., *Copeland R.S.* and Notton D.G. (2018) The family Ismaridae Thomson (Hymenoptera, Diaprioidea): First record for the Afrotropical region with description of fourteen new species. *African Invertebrates* 59, 127–163. GOLD OA, IF 0.516

27. Channumsin M., *Ciosi M.*, *Masiga D.*, Turner C.M.R. and Mable B.K. (2018) *Sodalis glossinidius* presence in wild tsetse is only associated with presence of trypanosomes in complex interactions with other tsetse-specific factors. *BMC Microbiology* 18 (Suppl 1), 163. GOLD OA, IF 2.829

28. *Chepchirchir R.T.*, *Macharia I.*, *Murage A.W.*, *Midega C.A.O.* and *Khan Z. R.* (2018) Ex-post economic analysis of push-pull technology in Eastern Uganda. *Crop Protection* 112, 356–362. GOLD OA, IF 1.92

29. *Chepkorir E.*, Venter M., Lutomiah J., Mulwa F., *Arum S.*, *Tchouassi D.P.* and *Sang R.* (2018) The occurrence, diversity and blood feeding patterns of potential vectors of dengue and yellow fever in Kacheliba, West Pokot County, Kenya. *Acta Tropica* 186, 50–57. S, IF 2.509

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31. *Cheruiyot D.*, *Midega C.A.O.*, Van den Berg J., Pickett J.A. and *Khan Z.R.* (2018) Suitability of brachiaria grass (*Brachiaria* spp.) as a trap crop for management of *Chilo partellus*. *Entomologia Experimentalis et Applicata* 166, 139–148. doi: 110.1111/eea.12651. S, IF 1.454

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33. *Cheruiyot S.K.*, *Lattorff H.M.G.*, Kahuthia-Gathu R., Mbugi J.P. and *Muli E.* (2018) Varroa-specific hygienic behaviour of *Apis mellifera scutellata* in Kenya. *Apidologie* 49, 439–449. doi:410.1007/s13592-13018-10570-13596. GOLD OA, IF 2.856

34. *Cheseto X.*, *Kachigamba D.L.*, Bendera M., *Ekesi S.*, Ndung'u M., Beck J.J. and *Torto B.* (2018) Identification of glutamic acid as a host marking pheromone of the African fruit fly species *Ceratitis rosa* (Diptera: Tephritidae). *Journal of Agricultural and Food Chemistry* 66, 9933–9941. doi.org/9910.1021/acs.jafc.9938b04481. S, IF 3.412

35. *Chia S. Y.*, *Tanga C. M.*, *Khamis F. M.*, *Mohamed S.A.*, *Salifu D.*, *Subramanian S.*, *Fiaboe K. K. M.*, *Niassy S.*, van Loon J. J. A., Dicke M. and *Ekesi S.* (2018) Threshold temperatures and thermal requirements of black soldier fly *Hermetia illucens*: Implications for mass production. *PLoS One* 13(11), e0206097. https://doi.org/0206010.0201371/journal.pone.0206097. GOLD OA, IF 2.766

36. *Chia S. Y.*, *Tanga C. M.*, Osuga I.M., *Mohamed S.A.*, *Khamis F. M.*, *Salifu D.*, *Subramanian S.*, *Fiaboe K. K. M.*, *Niassy S.*, van Loon J. J. A., Dicke M. and *Ekesi S.* (2018) Effects of waste stream combinations from brewing industry on performance of black soldier fly, *Hermetia illucens* (Diptera: Stratiomyidae) *PeerJ* 6, e5885. doi: 5810.7717/peerj.5885. GOLD OA, IF 0.00

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38. *Cross F. R.* and *Jackson R. R.* (2018) When it looks and walks like an ant. *Learning & Behavior* 46, 103–104. doi: 10.3758/s13420-13017-10311-13420. . GOLD OA, IF 1.434

39. De Moraes C.M., *Wanjiku C.*, Stanczyk N.M, Pulido H., Sims J.W., Betz H.S., Read A.F., *Torto B.* and Mescher M.C. (2018) Volatile biomarkers of symptomatic and asymptomatic malaria infection in humans. *Proceedings of the National Academy of Sciences of the United States of America* 115, 5780–5785. www.pnas.org/cgi/doi/5710.1073/pnas.1801512115. GOLD OA, IF 9.661

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41. Dhau I., Adam E., Mutanga O., Ayisi K., *Abdel-Rahman E.M.*, Odindi J. and Masocha M. (2018) Testing the capability of spectral resolution of the new multispectral sensors on detecting the severity of grey leaf spot disease in maize crop. *Geocarto International* 33, 1223–1236. doi:1210.1080/10106049.10102017.11343391. S, IF 1.759

42. *Diiro G.*, Seymour G., *Kassie M.*, *Muricho G.* and *Muriithi B.W.* (2018) Women's empowerment in agriculture and agricultural productivity: Evidence from rural maize farmer households in western Kenya. *PLoS ONE* 13(5), e0197995. https://doi.org/0197910.0191371/journal.pone.0197995. GOLD OA, IF 2.766

43. Douglas M. R., Chang, J., Begum, K., *Subramanian, S.*, Tooker, J. F., Alam, S. N. and Ramasamy, S. (2018). Evaluation of biorational insecticides and DNA barcoding as tools to improve insect pest management in lablab bean (*Lablab purpureus*) in Bangladesh. *Journal of Asia-Pacific Entomology*, *21*(4), 1326-1336. https://doi.org/10.1016/j.aspen.2018.10.007. S, IF 0.875

44. *Egonyu J. P.* and *Torto B.* (2018) Responses of the ambrosia beetle *Xylosandrus compactus* (Coleoptera: Curculionidea: Scolytinae) to volatile constituents of its symbiotic fungus *Fusarium solani* (Hypocreales: Nectriaceae). *Arthropod–Plant Interactions* 12, 9–20. doi: 10.1007/s11829-11017-19552-11822. S, IF 1.591

45. Ehounou G. P., Ouali-N'goran S.-W.M. and *Niassy S.* (2018) Assessment of entomophagy in Abidjan (Cote D'ivoire, West Africa). *African Journal of Food Science* 12, 6–14. https://doi.org/10.5897/AJFS2017.1589. GOLD OA, IF 0.00

46. *Essoung F. R. E.*, Chhabra S. C., Mba'ning B. M., *Mohamed S. A.*, *Lwande W.*, Lenta B. N., Ngouela S. A., Tsamo E. and Hassanali A. (2018) Larvicidal activities of limonoids from *Turraea abyssinica* (Meliaceae) on *Tuta absoluta* (Meyrick). *Journal of Applied Entomology* 142, 397–405. S, IF 1.641

47. *Fite T.*, *Tefera T.*, Negeri M., Damte T. and Sori W. (2018) Management of *Helicoverpa armigera* (Lepidoptera: Noctuidae) by nutritional indices study and botanical extracts of *Millettia ferruginea* and *Azadirachta indica*. *Advances in Entomology* 6, 235–255. https://doi.org/210.4236/ae.2018.64019. GOLD OA, IF 0.00

48. Ganyo E.Y., Boampong J.N., *Masiga D.K.*, *Villinger J.* and Turkson P.K. (2018) Haematology of N'Dama and West African short horn cattle herds under natural *Trypanosoma vivax* challenge in Ghana [version 1; referees: awaiting peer review]. *F1000Research* 7, 314 (doi: 310.12688/f11000research.14032.12681). GOLD OA, IF 0.00

49. Gurr G.M., Reynolds O.L., Johnson A.C., Desneux N., Zalucki M.P., Furlong M.J., Li Z., *Akutse K.S.*, Chen J., Gao X. and You M. (2018) Landscape ecology and expanding range of biocontrol agent taxa enhance prospects for diamondback moth management: A review. *Agronomy for Sustainable Development* 38, 23. https://link.springer.com/article/10.1007/s13593-13018-10500-z. GOLD OA, IF 4.503

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51. *Hashim I.*, Mamiro D.P., Mabagala R.B. and *Tefera T.* (2018) *In vitro* and *in vivo* evaluation of microbial agents for management of rice blast disease in Tanzania. *World Journal of Agricultural Sciences* 14, 108–117. GREEN OA, IF 0.00

52. *Hashim I.*, Mamiro D.P., Mabagala R.B. and *Tefera T.* (2018) Smallholder Farmers' Knowledge, Perception and Management of Rice Blast Disease in Upland Rice Production in Tanzania. *Journal of Agricultural Science* 10, 137–145. 2018.doi:http://dx.doi.org/2010.5539/jas.v2010n2017p2137. GOLD OA, IF 1.186

53. Hussain M., *Akutse K. S.*, Lin Y., Chen S., Huang W., Zhang J., Idrees A., Qiu D. and Wang L. (2018) Susceptibilities of Candidatus *Liberibacter asiaticus*-infected and noninfected *Diaphorina citri* to entomopathogenic fungi and their detoxification enzyme activities under different temperatures. *MicrobiologyOpen* 2018, e607. doi: 610.1002/mbo1003.1607. GOLD OA, IF 0.00

54. *Idriss G. E. A.*, *Mohamed S.A.*, *Khamis F.*, Du Plessis H. and *Ekesi S.* (2018) Biology and performance of two indigenous larval parasitoids on *Tuta absoluta* (Lepidoptera: Gelechiidae) in Sudan. *Biocontrol Science and Technology* 28, 614–628. doi: 610.1080/09583157.09582018.01477117. S, IF 0.918

55. *Irungu F. G.*, *Mutungi C. M.*, Faraj A. K., Affognon H., *Tanga C.*, *Ekesi S.*, Nakimbugwe D. and *Fiaboe K. K. M.* (2018) Minerals content of extruded fish feeds containing cricket (*Acheta domesticus*) and black soldier fly larvae (*Hermetia illucens*) fractions. *International Aquatic Research* 10, 101–113. https://doi.org/110.1007/s40071-40018-40191-40078. GOLD OA, IF 0.00

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57. Irungu F.G., *Mutungi C.M.*, Faraj A.K., Affognon H., Kibet N., *Tanga C.*, *Ekesi S.*, Nakimbugwe D. and *Fiaboe K.K.M.* (2018) Physico-chemical properties of extruded aquafeed pellets containing black soldier fly (*Hermetia illucens*) larvae and adult cricket (*Acheta domesticus*) meals. *Journal of Insects as Food and Feed* 4, 19–30. https://doi.org/10.3920/JIFF2017.0008. S, IF 0.00

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