

Vision and Strategy 2021-2025





Schwarzia sp. (Hymenoptera: Apidae) to be named *icipensis* (in litt.) is a cleptoparasitic bee that invades the nests of pollen-collecting bees, deposits its egg(s), and the larvae that hatch from the eggs feed on the pollen of the unsuspecting host. It is a previously undescribed species named after *icipe* to commemorate its 50th Anniversary.

Vision and Strategy

2021-2025

International Centre of Insect Physiology and Ecology (*icipe*)

PO Box 30772-00100 Nairobi, Kenya

icipe@icipe.org

www.icipe.org

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Writing: Bruce Pengelly

Editing: Dolorosa Osogo

Design and Layout: Brian Mwash

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Foreword

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

This Vision and Strategy 2021–2025 builds on the Centre’s achievements and experiences and incorporates the recommendations of the *icipe* Periodic External Review (IPER) undertaken in 2018. That review was expansive in its endorsement of what *icipe* research and development and longstanding commitment to capacity building has achieved. The reviewers commended the Centre’s management and administration, and recognised the quality and dedication of its research, capacity building and support teams.

Building on this track record and the IPER, this Vision and Strategy is developed for effective and ambitious deployment of *icipe*’s capability in response to the health, food security and environmental risks faced by people in Africa. It describes how we will explore opportunities for new enterprises that are based on insects and their products, and advance discoveries that enable

safer and more sustainable solutions to control pests and diseases using new and emerging science disciplines that *icipe* has at hand. The Vision and Strategy is also shaped by the expansion of *icipe*’s long commitment to building Africa’s research capability and to taking its research findings to users for impact.

The strategy aligns *icipe*’s effort with global and regional policy initiatives (such as the 2030 Sustainable Development Goals and the Science, Technology and Innovation Strategy for Africa [STISA–2024]) and in doing so, enables the Centre to contribute to the improvement of lives on the continent and around the world.

It is with much pleasure that we present *icipe*’s Vision and Strategy 2021–2025 with the confidence that it will enable *icipe* to continue as the leader in insect and arthropod science, research and innovation in Africa.



Dr Segenet Kelemu
Director General & CEO



Professor Dr Bill Hansson
Chair, Governing Council

Executive Summary

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

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

As at February 2020, the Centre has >646 staff based in Kenya, Ethiopia and Uganda, and has adopted a research structure built around four research Health Themes (Human, Animal, Plant and Environmental Health — the 4-H). Across those Themes, the Centre employs a diverse range of science disciplines to achieve impact. Its science and scientists are globally recognised and respected, and its scientific publication citation metrics are impressive.

icipe's impacts are achieved via three pathways: scientific discoveries and subsequent *icipe*-developed tools and practices are used by farmers and rural and urban communities to improve their livelihoods and health. Integrated Pest Management in fruit and vegetable production, push–pull technology that controls stemborers and other pests in maize farming systems, and infused collars that control tsetse fly in cattle are just some examples of the contributions for which *icipe* is currently recognised.

icipe also plays a significant role in applying its expertise to develop science-based national and regional policies associated with agriculture, livestock production, human health and the environment.

Alongside its research focus, *icipe* has a long history as a leader in developing future generations of researchers and teachers in entomology, plant protection and health. Its current alumni membership stands at 770 and many of these

scientists have gone on to be leaders in the national African research and innovation system.

Despite economic, health and food security advancements over the past decades, the challenges facing sub-Saharan Africa (SSA) are not diminished. As problems are solved, new ones appear. Climate change, population growth, urbanisation, and increased trade and people movement are some of the drivers that are presenting Africa and the world with a new generation of challenges. In response, *icipe* has reshaped its strategy to meet those challenges and apply new science and technologies to find solutions. The Vision and Strategy 2021–2025 (V&S 2021–2025) balances the continuation of insect-based science across the 4-H Themes (Plant Health, Animal Health, Human Health and Environmental Health) with a stronger focus on achieving impacts.

icipe will take several measures to better support the **uptake of its research**. These measures include more of its projects and programmes being undertaken using a participatory action research (PAR) paradigm and using the resultant stronger engagement with national and regional innovation system actors to achieve impact. It will also establish a Biocontrol Consortium of private sector and other stakeholders that will, amongst other roles, fast-track commercialisation of *icipe*'s products, provide external advice to the Centre on research and capacity building priorities, and provide a conduit to national and regional policy and regulatory agencies.

icipe recognises the need to deliver the outcomes of its research more widely across sub-Saharan Africa. In response, *icipe* will use the PASET-RSIF (Partnership for skills in Applied Sciences, Engineering and Technology - Regional Scholarship and Innovation Fund) initiative and networks of existing partnerships as entry points to multiple

selected countries in West, Central and Southern Africa with the view to building a portfolio of research that meets local needs and priorities in these subregions.

Notwithstanding emerging priorities, *icipe* has already identified several applied and basic research domains that are already in-train and will form part of its research thrust in 2021–2025 as outlined below.

Invasive insect species will continue to be a major concern across Africa and, in response, *icipe*'s research in the coming years will focus on the underpinning science that will support the establishment of better surveillance, forecasting and early warning systems, and the development of national and regional policies to reduce the risks from invasives.

Insect biodiversity loss is a growing concern across the globe. *icipe* will be prioritising research towards better knowledge of insect physiology and phenology, and ecological networks that can maintain and improve connectivity of landscapes, agroecology and resilience of the environment in the face of climate change and landscape change.

Research investigating the potential role of **insects for food and feed** and other uses will be expanded towards the practices and policies needed to enable insects to fill a role as a major food and feed source for humans and livestock in Africa and elsewhere, and in doing so address food insecurity and malnutrition while supporting mitigation action to reduce greenhouse gas emissions from livestock.

Microbiome research at *icipe* will be advanced with the aim of finding strategic entry points to reduce disease transmission and control crop pests. *icipe* will build knowledge and understanding on the unique dissemination pathways of some symbionts, such as vertical transmission, which could create a self-regenerating system of control. Microbiome research will also be directed towards improving the effectiveness and productivity of beneficial species. *icipe* will be a leading institution in the field of arthropod symbiosis in Africa. Since many of the tools and techniques used to study microbial symbionts are shared across the different

subject areas, enormous potential exists for synergistic collaborations across all of *icipe*'s themes.

icipe will expand its research agenda to study and promote **soil health**. Poor soil fertility remains a key constraint to successful crop production in sub-Saharan Africa. Below-ground pests (such as plant-parasitic nematodes) are ill-researched, yet become important pests, especially under poor agricultural practices. On the other hand, plant rhizospheres and soils harbour an undiscovered treasure of microbes (including endophytes) that have the potential to be harnessed for the development of novel biopesticides.

The **increasing impacts of climate change** being felt through greater incidences of zoonoses and transboundary animal diseases point to the need for more urgent coordinated holistic responses across science disciplines. In response, *icipe* will build a stronger interdisciplinary approach to its research via adoption of the **One Health concept** and integration of the research focus and disciplines of the 4-H Themes.

The **expansion of capacity building** at *icipe*, especially its new coordinating role of the PASET-RSIF programme, will be a major growth area for *icipe* over the next five years.

Expanding its research and development role in Africa requires a continuation of sound governance, management and continuing adjustment to the Centre's capability and *icipe* has signalled a few actions in this regard. These include gradual renewal of personnel, skills and representation in the Governing Council membership, sustained growth in budget, primarily by growth in larger grants/special programmes, an increase in the financial reserves that the Centre will set aside to accommodate possible funding/currency fluctuations, and a continued growth in the proportion of its research portfolio, which operates under a full cost recovery model. Several new strategic appointments have also been flagged for the coming years and include the appointment of a new Director-level position to oversee the Centre's strategy and its partnerships, and other senior appointments in both administrative and research roles.



Cotesia icipe (Braconidae: Hymenoptera), an indigenous solitary parasitoid of major armyworm larvae such as cotton leafworm, *Spodoptera littoralis*; Beet armyworm, *Spodoptera exigua* and fall armyworm, *Spodoptera frugiperda*. Field assessments in Kenya, Ethiopia and Tanzania by *icipe* has revealed up to 45% field level parasitism of fall armyworm in Ethiopia, showing its high potential in the biological control of the invasive pest.



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

Analysis of the external and internal environment

Section 1: Setting the scene – Africa towards 2100

At the time of *icipe*'s establishment in 1970, Africa had a population of just 360 million. Since then Africa has been transformed through advancements in the fields of education, science, health, agricultural productivity and overall economic development.

Despite the progress made so far, many of the challenges of 1970 remain, and others (such as loss of biodiversity, ecosystem services, natural resource degradation and impacts of climate change) have risen in prominence. The solutions to these challenges will continue to depend, directly or indirectly, on the application of the rapid advances in science and technology. However, the solutions formulated in the next decades will increasingly come from the expanding indigenous African innovation system, of which *icipe* continues to be an integral and much respected member.

One of the greatest challenges globally is that practice and policy solutions will have to be found in a world in which insect biodiversity is declining at an alarming rate.

disease control, food for humans, feed for birds and mammals, and waste degradation. Stemming the rapid decline in insect biodiversity while simultaneously using the available insect-based science to deliver impacts is a challenge whose scale and potential implications have only recently been recognised.

Africa in the next 50 years will continue its rapid growth in population and economic development. In just 15 years (2035), > 50% of its population will live in urban environments. Africa will also become more connected to global trade and

the intra-continental trade will continue to grow. Regional policy decisions are enhancing the rate of economic growth and provision of services across the continent. A recent policy initiative for a continent-wide free trade agreement (African Continental Free Trade Area [ACFTA]) reached its operational phase in 2019, creating a 55-nation bloc with a total worth of \$3.4 trillion, with expectations that the initiative will quickly double intra-African trade¹.

Improvements in nutrition and sanitation, and a reduction in the most serious diseases (such as malaria) has seen the life expectancy grow from ca. 50 years in 1980, to 60 years in 2015². In the decade to 2015, infant mortality for the continent fell by ~30%. Africa's population in 2019 was about 1.3 billion; this is expected to double by 2050 and reach 4.5 billion in 2100. As might be expected with such population growth rates, Africa is experiencing continuing challenges in food security after a decade of slow but consistent improvement. After years of decrease and reaching 20.9 in 2015, the Prevalence of Undernourishment index for SSA rose again in 2016 and reached 22.8 in 2018³, which is almost twice as high as for any other region on the planet.

The rapid economic growth and development, and equally rapid growth in population and demand for food and services, are placing ever more impositions on Africa's environment. The pressure on land in many parts of Africa is extreme,

1 <https://www.weforum.org/agenda/2018/01/why-africas-best-trading-partner-is-itself/>

2 <https://www.hoover.org/research/africa-2050-demographic-truth-and-consequences>

3 <http://www.fao.org/state-of-food-security-nutrition/en/>

especially in areas with the highest population density, such as the Great Lakes region. These changes present an increasing risk to Africa's unique biodiversity, which includes both wild relatives and landraces of domesticated crops and livestock, and the large pool of undomesticated species of microorganisms, plants, insects and related arthropods and wildlife, that together provide effective functioning of ecosystem services, opportunities to find novel solutions to certain zoonotic diseases (and in the case of wildlife, the basis for the continent's tourism industries⁴).

Trade and movement of people means that Africa is also experiencing devastating invasive insects and arthropods arriving accidentally from outside the continent on a regular basis.

Biosecurity measures that are conducive to trade across Africa, and at the same time effective in limiting invasive species arriving on the continent and being transported from country to country, will be a major challenge for Africa in the coming decades.

Hovering over the continent is the spectre of climate change, with predicted higher temperatures in the subtropics, greater aridity in southern Africa and higher rainfall in eastern Africa⁵. These changes are predicted to have most impact on rainfed agriculture, food security and human nutrition, but they will also modify the zones of disease prevalence and spread of invasive pests. Already, higher altitude areas in Ethiopia, Kenya, Rwanda and Burundi are experiencing malaria

where it did not occur before, while climate change-induced impacts of reduced rainfall in the northern Sahel are expected to reduce the incidence of the disease as the northern malaria boundary of West and Central Africa edges southwards.

Even though Africa has undergone transformation since *icipe* first commenced its journey as a key Centre within the research and development community, forecasted economic and population growth in the next decades points to future challenges that will require solutions based on new ideas and new knowledge from *icipe*'s research disciplines and priorities.

Globalisation, privatisation, digitisation and the fourth industrial revolution all provide growing opportunities for the development and deployment of transformative technologies that can be applied to Africa's key challenges. Together, these technologies and associated capacity building, i.e. continued and increased investment in science, research and innovation, provide the best opportunities for the youth and their future, while preserving the continent's natural resources.

The production and storage of food, its nutritional quality, climate change mitigation and adaptation, biodiversity conservation, and the management of pests and diseases and disease-carrying vectors are all factors that will play a part in shaping Africa's future. These challenges and opportunities have driven *icipe*'s strategy and investment over the past 50 years and will continue to do so as *icipe* enters its second half-century.

⁴ https://www.ipbes.net/system/tdf/spm_africa_2018_digital.pdf?file=1&type=node&id=28397.

⁵ https://climateanalytics.org/media/ssa_final_published.pdf



icipe Duduville campus, Nairobi, Kenya

Section 2: *icipe* and its role

icipe is an African Centre and a regional and global leader in research for development (R4D) through insects and related arthropods and their impacts on food security, human health, environmental sustainability and livelihoods.

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

Three key elements define *icipe*'s research strategy:

- (a) a focus on research domains in which insects and related arthropods have critical roles as vectors, pests or are the basis for beneficial uses (such as for food, feed, ecosystem services and value-added products, e.g. silk);
- (b) innovation that can be applied to develop sustainable and safe alternatives to reliance on agri-chemicals; and
- (c) highly valued R4D Capacity Building and Institutional Development (CBID).

These elements are all articulated in *icipe*'s mission statement which is to:

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

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

Enacting the Centre's mission by undertaking rigorous scientific research and developing and nurturing partnership networks demands that *icipe* has and holds true to a set of guiding principles that define who it is, and how it can be relied on to conduct itself (Box 1).

Box 1. *icipe*'s values

icipe's core values define who we are and provide the foundation for the Centre.

These values are based on:

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

Respectful and inclusive relationships

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

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

Integrity and innovation

icipe is committed to treating each other, our partners and others we work with, as valued colleagues, guided by open communication, collaboration, partnership, integrity and respect, to achieve our common goals.

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

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

Accountability and transparency

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

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

Included in these guiding principles is financial accountability and sustainability. Over the past five years, there have been considerable year-to-year fluctuations in the total budget and in the number of contracts associated with those totals. These fluctuations are indicative of an ever-changing donor environment and point to the significant challenges the Centre faces to build new capability, support innovative research and take its research outputs to impact in such an environment. In 2017, just five donors accounted for 55% of overall grant income and the top 11 donors (or about 20% of donors) accounted for >75% of restricted grant funding. The combination of year to year variation in donor contributions, the proportion of the total budget that can be considered core or unrestricted funds, and the sheer number of contracts and donors that are being serviced make financial management and sustainability one of the challenges for *icipe*'s Governing Council, senior management and the research teams who, in the end, have to deliver on the many contracts that collectively make up *icipe*'s research portfolio.

All progressive institutes take time to reflect on their progress and reshape their priorities. As part of that regular recalibration, *icipe*'s Governing Council initiated an external review in 2018. This review complemented *icipe*'s progress in research quality, the impacts it was having on the ground, its network of partnerships, its outstanding achievements in capacity building, and the positive changes implemented in management and governance. The reviewers also made a series of recommendations (Box 2) that are now being incorporated into this Vision and Strategy 2021–2025.

Box 2. Recommendations from the 2018 *icipe* Periodic External Review (IPER)

1. Continued adoption of One Health as an integrating paradigm for the Centre.
2. Appoint strategic new positions and skills that will give *icipe* the enhanced capability to undertake its research and development agenda.
3. Strengthen data management practices to ensure long term data security and its accessibility for new research enquiries.
4. Dedicate more skills and resources to encourage adoption of *icipe*'s tools and innovations.
5. Take steps to enable countries beyond East Africa to benefit more from *icipe*'s research and development programme.
6. Continue and expand *icipe*'s long standing commitment to regional capacity building and institutional development.
7. Ensure financial sustainability by transitioning towards a full cost recovery model.

Section 3: *icipe's* place in the African research and development environment

As a leader and key Centre for scientific research and innovation in Africa for 50 years, *icipe* has contributed to the delivery of major regional research and development plans, policies and initiatives.

The most pertinent are the 2030 Sustainable Development Goals (SDGs), the African Union's Comprehensive Africa Agricultural Development Programme (CAADP), the Science, Technology and Innovation Strategy for Africa 2024 (STISA 2024), and the African Union (AU) Agenda 2063, which continues beyond the SDGs, CAADP and STISA timelines.

The AU Agenda 2063 vision is for “an integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the international arena”. Growth, sustainability, human capital, gender and global partnerships are key aspirations for 2063 (Box 3), and these attributes are reflected throughout *icipe's* research, innovation and capacity building initiatives.

The 2030 Agenda for Sustainable Development adopted by the United Nations in 2015, contains 17 SDGs. In many respects, *icipe's* work is aligned to all the SDGs, but at its core, contributes directly to SDGs 1, 2, 3, 4, 5, 7, 9, 10, 15 and 17 (Box 4) as evidenced by the research focus on

Box 3. African Union Aspirations for 2063 as published in the AU Malabo Declaration on Agriculture and Postharvest Losses 2015

1. A prosperous Africa based on inclusive growth and sustainable development.
2. An integrated continent, politically united and based on the ideals of Pan-Africanism and the vision of Africa's Renaissance.
3. An Africa of good governance, democracy, respect for human rights, justice and the rule of law.
4. A peaceful and secure Africa.
5. An Africa with a strong cultural identity, common heritage, shared values and ethics.
6. An Africa whose development is people-driven, relying on the potential of African people, especially its women and youth, and caring for children.
7. Africa as a strong, united and influential global player and partner.

human, plant, animal and environmental health, its sustained and innovative commitment to postgraduate education across SSA, and its focus on research for development that provides new employment opportunities and better livelihoods for women and youth. *icipe's* work is also well aligned with the Common African Position (CAP) on the Post 2015 Development Agenda.

In 2014, the African Union, through the New Partnership for Africa's Development (NEPAD) (now the African Union Development Agency [AUDA-NEPAD]), developed STISA 2024. The STISA 2024 illustrates Africa's strategy to place science at the heart of development efforts. The four pillars of action that STISA 2024 targets to

Box 4. United Nations 2030 Sustainable Development Goals adopted in 2015

1. End poverty in all its forms
2. Zero hunger
3. Ensure healthy lives and promote well-being for all at all ages.
4. Quality education.
5. Achieve gender equality and empower all women and girls.
6. Ensure access to water and sanitation for all.
7. Ensure access to affordable, reliable, sustainable and modern energy.
8. Promote inclusive and sustainable economic growth, employment and decent work for all.
9. Build resilient infrastructure, promote sustainable industrialization and foster innovation.
10. Reduce inequalities within and among countries.
11. Make cities inclusive, safe, resilient and sustainable.
12. Ensure sustainable consumption and production patterns.
13. Take urgent action to combat climate change and its impacts.
14. Conserve and sustainably use the oceans, seas and marine resources.
15. Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss.
16. Promote just, peaceful and inclusive societies.
17. Revitalize the global partnerships for sustainable development.

achieve its goals are: building and/or upgrading research infrastructures; enhancing professional and technical competencies; promoting entrepreneurship and innovation; and providing an enabling environment for science, technology and innovation development on the African continent. *icipe*'s capacity building, research and innovation activities are thus well aligned with continental development aspirations and initiatives.

Some of *icipe*'s most crucial actions in support of STISA 2024 are its commitment to capacity building via partnerships with African universities, and provision of high-quality mentoring that lays the foundation for careers, research and tertiary training in Africa.

partnering with the private sector to commercialise several of its technologies, including biopesticides, insect attractants and repellents, demonstrates the practicality of translating research into useful products for the benefit of society and alignment with CAADP and STISA 2024.

In addition to alignment with overarching regional plans and policies, *icipe* is an active and long-standing partner with some of the most important African regional bodies. These include partnerships with the Forum for Agricultural Research in Africa

In addition to its roles in postgraduate training, *icipe* provides farmers, pastoral communities and health practitioners with capacity building that is designed to facilitate information flow and uptake of new technologies resulting from its research. *icipe*'s track record in

(FARA), the African Academy of Sciences (AAS), the regional economic community organisations such as the East Africa Community (EAC), Economic Community of West African States (ECOWAS) and the Common Market for Eastern and Southern Africa (COMESA), where the focus of the relationships has been on developing harmonised biopesticide and phytosanitary standards and regulations. *icipe* also has close relationships with the three SSA regional agricultural research and development organisations: Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA); the West and Central African Council for Agricultural Research and Development (CORAF/WECARD); and the Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA). These regional partnerships, along with partnerships with national agriculture and health agencies, ensure that partners are aware of *icipe*'s research outcomes and enable it to be a contributor in the establishment of regional policy.

icipe is one of the 15 regional centres of the Stockholm Convention on Persistent Organic Pollutants (POPs) undertaking capacity building and technology transfer in developing member countries to achieve elimination or reduction of the use of POPs. *icipe* is also designated as a Food and Agriculture Organization of the United Nations (FAO) Reference Centre for vectors and vector-borne animal diseases, and a World Organization for Animal Health (OIE) Collaborating Centre for Bee Health in Africa, and continues to work with the World Health Organization (WHO) and International Atomic Energy Agency (IAEA) to improve national and regional vector control capability and deal with invasive species across Africa.

Section 4: Blending 4-Health Themes with Capacity Building; *icipe*'s unique dimension

Of *icipe*'s >646 staff, 70% have technical roles and the remainder form the Centre's support teams. *icipe*'s entomological base is underpinned by the science disciplines of chemical ecology, molecular biology, biotechnology, insect pathology, taxonomy and systematics, ecology, data management, modelling, remote sensing, biostatistics and social science.

icipe's research portfolio is organised around four research Health Themes (4-H) that are identified with specific sectors and defined by their outcomes in that sector: **Human Health, Animal Health, Plant Health and Environmental Health**. A fifth cross-cutting "theme", **Capacity Building and Institutional Development (CBID)** delivers across all themes. These 4-H Themes are supported by eight **Research Units** that together form *icipe*'s organisational research matrix (see Figure 1). Each research theme addresses major development challenges for Africa, of which malaria control,

management of the parasitic weed striga in maize crops, control of a range of crop pests including invasive species through biopesticides development, ecological management technologies and control of tsetse fly and trypanosomiasis in livestock are just a few. Across its entire portfolio of research and development as well as research support and in its interaction with partners, the Centre consistently strives to meet the principle of gender equality that is at the core of the Centre's ethos (Box 5).

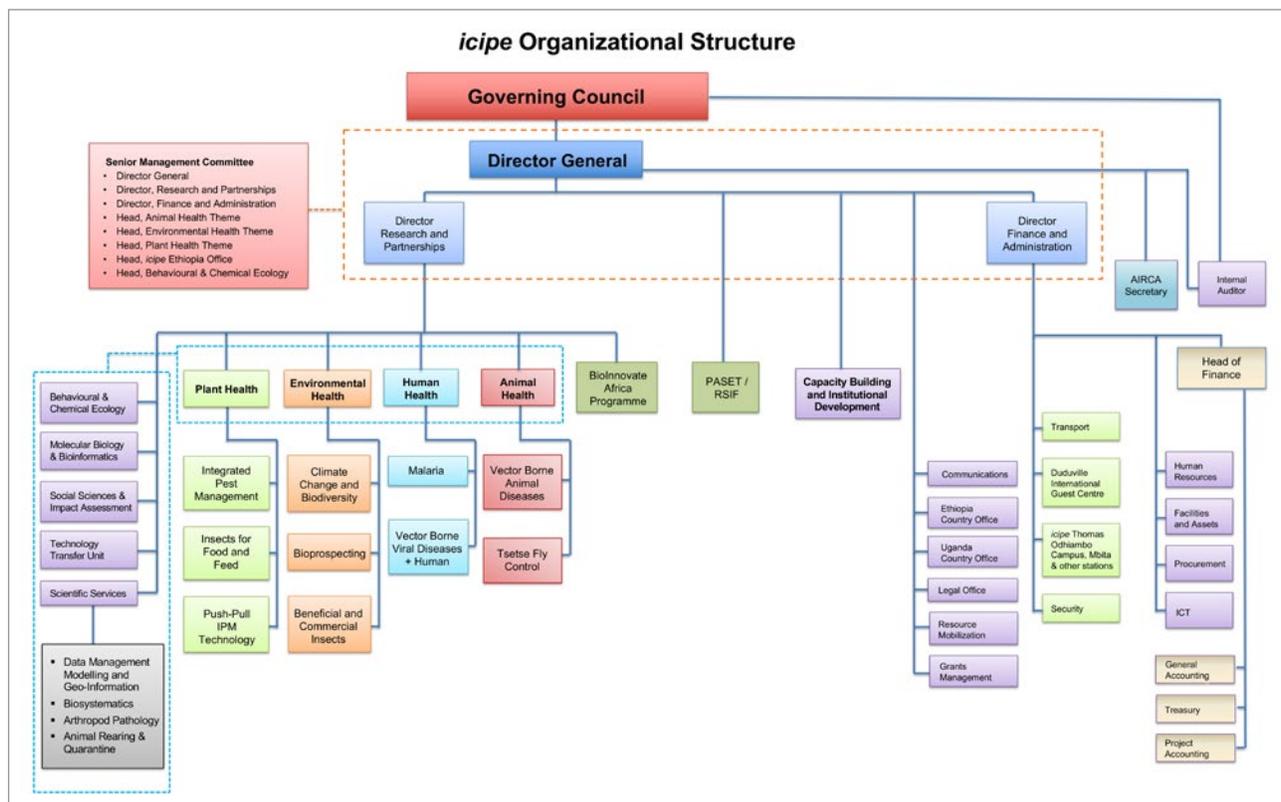


Figure 1. *icipe*'s organisational research matrix.

Box 5. Gender equality in the workforce, in capacity building and in delivering its research to communities

Gender equality is among *icipe*'s key values and is central to its strategic objectives. It strives to achieve that equity by empowering women in its own workforce and by applying gender equity principles across its research for development program, its capacity building initiatives and by influencing its partners.

In its workplace, *icipe*:

Provides equal career opportunities for men and women and ensures access to capacity development and training measures is provided equally;

1. Strives for gender parity in matters of recruitment and career development, including employment in senior scientist and decision-making positions;
2. Creates a gender-inclusive workplace culture that enhances recruitment and retention of female staff.

icipe is also committed to promoting gender equality through its R&D work through each of the impact pathways defined in the Pathway to Impact diagram (Figure 2). These are:

To foster gender equality in access to and uptake of new technologies by (a) identifying and incorporating preferences of women, men, and youth into technology design; (b) supporting alleviation of women's constraints to technology adoption; and (c) engaging partners with gender expertise or building that capacity in our partners.

1. Gender equality in capacity development at *icipe* is pursued three ways: (a) gender equality in the intake and advancement of MSc and PhD students; (b) ensuring gender awareness and gender capacity in partners that are part of technology development and transfer; and (c) where needed, ensuring that women, men, and youth, as project beneficiaries, all have opportunities to receive appropriate training.
2. In the policy influence pathway, *icipe* researchers generate evidence and knowledge to inform policies in support of gender equality in project implementation and outcomes.

Box 6. Tungiasis

Sand flea disease (tungiasis) is a highly neglected parasitic skin disease which inflicts pain and suffering on millions of people in sub-Saharan Africa. Children, elderly and the disabled carry the highest disease burden with prevalence in schools in affected communities in Kenya ranging from 15% and 60%. In resource-poor communities with limited medical care and ability to pay for medications, prevention is the best control measure since there is currently no effective, safe and simple treatment. The lifecycle of the sand flea, *Tunga penetrans* is poorly understood and little is known of the ecology of off-host stages, and transmission dynamics, including the physical, psychosocial and economic environment, linking the human, the animal host and the parasite. *icipe* is spearheading pioneering work on understanding the disease ecology and recently reported from a study in coastal Kenya that public health policies such as sealing houses and classroom floors and daily feet washing with soap could cut the number of tungiasis cases in school-aged children by 70%. Over the next five years *icipe* will investigate the potential impact of tungiasis on neurocognitive, mental health and scholastic outcomes of children, the socio-cultural determinants to infestation, and build understanding of the developmental conditions required for the sand flea. Together, these new findings should enable the development of new prevention and treatment tools.

The **Human Health Theme's** most prominent programme has been the pursuit of malaria control through a focus on mosquito ecology, behaviour and the transmission of the malaria-causing *Plasmodium* parasites. *icipe* has developed several improved monitoring tools and developed and deployed solar-powered mosquito traps which capture and then kill harmful mosquitoes, and bio-larvicides that reduce mosquito populations in rural and urban environments. The Theme has also targeted other important vector-borne diseases of East Africa, including dengue, Rift Valley fever, leishmaniasis, schistosomiasis (together often labelled "neglected tropical diseases" (NTDs)). Its research on diseases transmitted by insects other

Box 7. Improved understanding of epidemiology of emerging and re-emerging viral infections/diseases

icipe scientists have discovered a virus closely related to Rift Valley fever virus that is transmitted by sand flies and found to infect humans in the Rift Valley and North-eastern Kenya. This new discovery has now led to further investigation about its potential contribution to the cause of acute fevers in humans from different ecologies of Kenya that mimic malaria and are often wrongly diagnosed and treated. *icipe* is applying new diagnostic tools to identify these emerging agents that may contribute to fever illnesses in the study areas. The findings have also opened new avenues to examine an array of other blood feeding insects which are poorly studied with regards to their role in the spread of viruses of potential threat to humans.

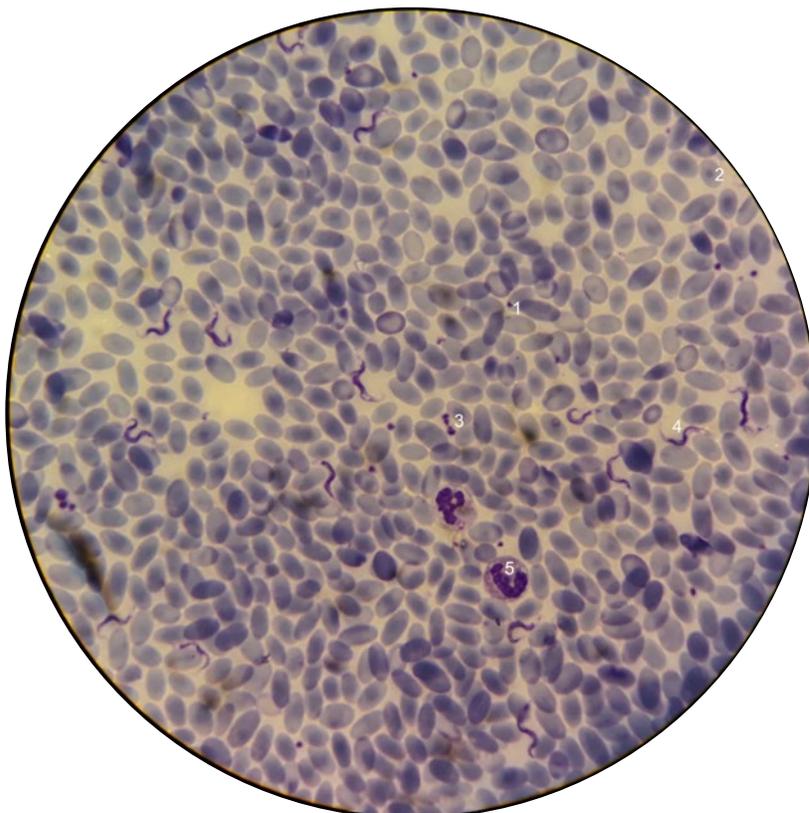
than mosquitoes reflects *icipe*'s capacity to apply its science to diverse health issues (Box 6,7).

The approach taken by the **Animal Health Theme** has been similar to that taken by the Human Health Theme; vector ecology, behaviour and population ecology of the arthropods that transmit some of the most important livestock diseases of the region. This Theme has pioneered the use of tsetse-

repellent collars for protecting domestic animals from tsetse flies and the parasites they transmit. More recent research to control tick-transmitted diseases, especially East Coast Fever in cattle, has identified botanicals, anti-tick pasture plants and semiochemicals that modify the behaviour of ticks and prevent them from finding mates and hosts. Similar work has established intriguing principles under which stable flies, important vectors of a range of livestock diseases, might be controlled (Box 8).

Box 8. Oviposition cues for stable flies, *Stomoxys calcitrans* for management

The stable fly, *Stomoxys calcitrans* has global distribution and is a vector of multiple pathogens, including viruses, bacteria, protozoa and helminths. They feed on diverse wild and domestic animals especially camel, which allows them to spread pathogens across species. Our research shows that female stable flies locate and select vertebrate herbivore dung using simple chemicals, in which they lay their eggs. The choice influences the fitness of the larvae that result. These oviposition cues can be used for the management of the stable fly. In our current research we are refining the use of these cues to selectively target gravid females as a population suppression strategy.



Camel blood infected with multiple pathogens: Light micrographs of Giemsa-stained camel blood sample smears, (1) *Anaplasma marginale* appear as dense, rounded and deeply stained intraerythrocytic bodies. Most of these bodies are located on or near the margin of the erythrocyte (2) *A. centrale*, as in the latter most of the organisms have a more central location in the erythrocyte (3) *Mycoplasma spp.* see extracellular location (4) *Trypanosoma evansi* with a small sub terminal kinetoplast at the pointed posterior end, a long free flagellum and a well-developed undulating membrane (5) Cytoplasmic inclusion due to anaplasma.



Climate-smart push–pull plot developed for more arid agro-ecologies. Sorghum is intercropped with greenleaf desmodium (*Desmodium intortum*) with *Brachiaria mulato II* trap plant.

The **Plant Health Theme** focuses on the control of Africa’s most debilitating pests and vectors of staple crops, particularly maize, as well as those attacking vegetables, fruits and industrial crops, especially coffee. A major research thrust of the Theme is on invasive pests, increasingly using a systems approach, including modelling, forecasting and the use of big data. The Theme also undertakes research on pests in soils and storage, and on the use of insects for human food and animal feed. A key paradigm for all research interventions is that they are based on an integrated pest management (IPM) principle, with a strong focus on biological control. One significant component of the research undertaken by the Plant Health Theme relies on the enhanced understanding of innate plant defence mechanisms that function via early herbivory alert and plant signaling. This approach has now reached the level of wide-scale dissemination and adoption of the climate-resilient push–pull system adapted to both sub-humid and dryland conditions. (Box 9).

Box 9. *Spodoptera frugiperda*, the fall armyworm, invaded Africa in 2016, and already affects 49 Africa countries, causing crop loss of up to 17.7 million tonnes per year in maize, its main host. Control using synthetic chemical pesticides faces challenges due to improper use, unaffordability, and eventually resistance.

Push-pull technology is an integrated pest management option that eliminates pesticide use by deploying chemical ecology principles. The technology involves ‘pulling’ insect pests with trap plants such as Napier grass or brachiaria grass, while ‘pushing’ them away from maize using desmodium as a repellent intercrop. At the same time, parasitoids and predators are attracted to the maize field by the grasses and desmodium. Furthermore, in the soil, chemicals secreted by desmodium roots inhibit attachment of germinated striga to maize roots and abort germination of striga seeds, rapidly depleting their reservoir in the soil. Push-pull technology has proven to be very effective against maize stemborers as well as Striga. So far, the technology has been implemented by more than 240,000 farmers in eighteen countries Africa, where it has increased maize yields from 1 to more than 3.5 tonnes per hectare.

icipe recently demonstrated that push-pull technology may present a formidable tool for the fight against fall armyworm. When multi-locational field surveys evaluated the effect of climate-adapted push-pull on fall armyworm through direct field observations and farmers’ perceptions in Kenya, Uganda and Tanzania, *icipe* found highly significant reductions in infestation and plant damage levels by fall armyworm larvae. Compared to maize monocrop plots, a reduction of 82.7% in average number of larvae per plant and 86.7% in plant damage was observed in climate-adapted push-pull plots. Also, maize grain yields were significantly higher, approximately 2.7 times, in the climate-adapted push-pull plots. As a result, farmers rated the technology very effective in reducing fall armyworm infestation and plant damage rates.

Push-pull technology represents the first documented integrated pest management tool for fall armyworm in Africa, and is well suited to the smallholder mixed farming systems in Africa. Other surprising benefits of push-pull technology are being discovered and documented, such as its improvement of soil fertility by fixing nitrogen, improvement of carbon sequestration and, recently, reduction in aflatoxin levels, illustrating the myriad possibilities of this amazing technology for the benefit of smallholder farmers.

Research aimed at developing IPM products to lessen damage to vegetable and other crops caused by fruit flies, diamond back moths, thrips, leafminers and other crop pests is another priority for the Plant Health Theme. In this work, biopesticides and insect attractants, some now manufactured and marketed through East African commercial partners, are the innovations that reduce the damage from pests and do so without the environmental harm associated with more traditional chemical control methods (Box 10).

Box 10. Arthropod pests and vectors constrain the livelihoods of Africans by debilitating production of crops and livestock and through transmission of vector-borne diseases. In the absence of effective alternative management options to tackle these pests and vectors, there is extensive dependence on synthetic pesticides, with significant negative impacts on health and the environment. Biopesticides have proved to be effective and environmentally sustainable alternatives. Over the years, *icipe* has established a strong biopesticide research-for-development program underpinned by a large repository of arthropod pathogens, protocols for lab bioassays and field efficacy testing, and effective public-private partnerships to deliver new biopesticide products.

Biopesticides are pesticides that consist of a microorganism instead of a chemical as the active ingredient. Among these microorganisms, *icipe*'s greatest effort has been on fungi, particularly *Metarhizium anisopliae*. In partnership with private sector partners, notably the Real IPM-Biobest Company, *icipe* has developed and commercialized three *M. anisopliae* strains, ICIPE 69, ICIPE 78 and ICIPE 62, for the management of a variety of pests that attacks crops, while ICIPE 7 is at the final stages of registration for managing livestock ticks. The number of countries where these products are registered, and area treated by these products has increased significantly over the years. In 2018, biopesticide products based on *icipe*'s *M. anisopliae* strains were registered in eight sub-Saharan African countries, with over 89,000 ha treated.



Mature fall armyworm, *Spodoptera frugiperda* larva feeding on the maize tassel (top) and maize cob (bottom) impacting on pollination and yield.

The **Environmental Health Theme's** research emphasis is on monitoring biodiversity and building understanding of key ecosystem services related to plant-pollinator systems with a focus on bees. The bee health research ranges from basic research on behavioural mechanisms and genomics to applied studies on bee breeding, colony management, and product certification and market access (Box 11). The Theme also studies abundance and diversity of native bee species, especially stingless bees, their pollination efficiency, rearing methods and queen rearing/breeding to conserve genetic diversity and improve resilience to bee diseases and pests. The aim of this research is to gain a better understanding of the role of these species as “wild” pollinators in agricultural and natural habitats and potentially as alternative managed pollinators for a variety of crop plants.

An additional priority of this Theme is underpinning research and the development at scale of community-based enterprises that produce commercial honey, wax and raw silk, and on bee ecology and health, an issue of major concern globally. Integral to this work is youth entrepreneurship, where insect-based production systems provide the platform for youth to gain the expertise, finance and networks to get started on their own small enterprises (Box 12).



Box 11. The health of honeybees and native unmanaged bees can be impaired by a range of different factors that lead to reduced pollination services and crop yield. Environmental stress, pests and pathogens, and genetic diversity and vitality can alone, or in combination reduce colony health and function. As most beekeeping colonies are feral colonies and breeding has not been applied, genetic diversity and vitality is less important in Africa. *icipe's* bee research at the OIE (World Organisation for Animal Health) Collaborating Centre for Bee Health in Africa has established several baselines for stressors relevant for bee health. The use and types of agro-chemicals (e.g. pesticides) were identified through analysis of residues in bee products and has established it as a wide-spread risk factor for bees in Africa.

Pests and pathogens of honeybees in Africa haven been identified and found to be the same that are also known from Europe and North America. Amongst them is the ectoparasitic mite *Varroa destructor*, the most serious pest of honeybees globally, which has been first described for Kenya and Cameroon by *icipe*-led research. African bees are less affected by *Varroa* and two recent studies at *icipe* have shown that the behaviour of the bees during grooming of adults and inspecting cells with larvae and pupae is efficient to reduce the *Varroa* load. These two behaviours are stronger expressed in African bees compared to bees of European origin.

Box 12. Beekeeping and silk production can provide both employment opportunities and enhance community livelihoods in rural Africa. These small and medium honey and silk enterprises have spill over effects along the value chain to benefit many more people indirectly. *icipe* has a long history of research in commercial honey and silk production and has employed this expertise in an innovative research project, YESH (Young Entrepreneurs in Silk and Honey). The project, since 2016 has trained 12,332 youth (38% women) organized in over a thousand youth enterprises with appropriate knowledge and skills, and enabled 10,000 (30% are women) rural youth to gain meaningful employment and earn money from silk and honey production in two regions of Ethiopia. Five years after the project started, over 700 youth enterprises now have their own functioning beekeeping or silk farming businesses generating attractive income, and have taken the decisions to invest > \$500,000 of their own money in strengthening and expanding their enterprises.

As well as the work undertaken by these themes directly, *icipe* employs eight Research Units that undertake upstream research or provide critical technical support that is integral to the effectiveness of all themes. These units are:

- *Behavioural and Chemical Ecology (BCE)*
- *Molecular Biology and Bioinformatics (MBB)*
- *Arthropod Pathology (AP)*
- *Biosystematics (BS)*
- *Data Management, Modelling and Geo-information (DMMG)*
- *Social Sciences and Impact Assessment (SSIA)*
- *Technology Transfer (TT)*
- *Animal Rearing and Quarantine (ARQ)*

These units are shown on the Organizational Structure diagram and the Path to Impact diagram (Figures 1 and 2).

To foster more interdisciplinary and inter-theme interaction and synergy, *icipe* has adopted the One Health concept as a Centre-level strategic framework. The concept envisions the integration of research across all 4-H themes through a social-ecological systems framework targeted to specific problem areas. This concept has been used in other fora⁶, primarily in the area of zoonotic diseases that integrate animal, human and environmental health.

While *icipe*'s diverse research portfolio has delivered new knowledge and outcomes for Africa and other parts of the world, its longstanding focus on building research capacity across Africa is one of its sustained achievements. Between 1983 and 2019, 723 postgraduates (PhDs and MScs) from 33 African countries (plus 67 postgraduates from 15 countries outside of Africa) completed their training, including 242 through the African Regional Postgraduate Program in Insect Science (ARPPIS). Many of the ARPPIS graduates (~75%) are today contributing to Africa's future via their research, development or higher education roles across Africa.



Prof. Baldwyn Torto (seated, in safety goggles), Head of *icipe* Behavioural and Chemical Ecology and Mr. Onesmus Wanyama (extreme right), Unit Laboratory Manager, discussing results from an analysis of zebra skin odours with graduate students.

The proportion of women in the postgraduate programs has steadily increased so that 43% of students currently in the *icipe* postgraduate programs are women.

The African alumni (377 MSc, 346 PhD students, and more than 50 postdoctoral fellows) represent an outstanding community of researchers in relevant fields who are well-positioned to advance research for development and higher education on the continent. This is evidenced, for example,

by four *icipe* alumni members, all women, having taken the position of Vice Chancellor at public universities in Kenya in the past 10 years.

Although a large proportion of the training activities has been accomplished in Kenya, *icipe* has established linkages with key universities from a wider region across Africa. Within the last five years, *icipe* has partnered with 31 African and 15 non-African universities to various degrees of engagement in postgraduate training. Among these universities, several are key to *icipe*'s postgraduate training programs, including the

⁶ For example see <http://www.onehealthglobal.net/what-is-One-Health/>

University of Nairobi, Egerton University, Jomo Kenyatta University of Agriculture and Technology, and Kenyatta University in Kenya; North-West University and University of Pretoria in South Africa; the Universities of Bonn and Wurzburg in Germany; and Wageningen University and Research in the Netherlands.

The Centre's sustained commitment to capacity building was recognised and strengthened in 2018 and it was granted the role of Regional Coordination Unit for the Regional Scholarship and Innovation Fund (RSIF) of the Partnership for skills in Applied Sciences, Engineering and Technology (PASET) programme, which is an African-led initiative. RSIF is the first pan-African science fund that creates a mechanism for pooling funds from multiple contributors (including African governments, donors and the private

sector) and has an explicit focus on building the institutional capacity of African universities to train postgraduates to doctoral level with a parallel aim of increasing the participation of women in the research sector in Africa.

RSIF was established to fill gaps in knowledge that are critical for African growth and development by increasing the number of PhD and post-doctoral opportunities in Applied Sciences Engineering and Technology (ASET).

RSIF complements *icipe's* other regional initiative, the BioInnovate Africa programme, whose objective is to increase the capacity of scientists and innovators in Eastern African universities, research institutes and private companies to translate innovative biological science-based ideas and technologies into

practical application in society and build functional innovation ecosystems.

This is an important role for Africa and for *icipe*. It has necessitated a revision of how *icipe* considers in what way its elevated role in capacity building can deliver impacts across Africa (See Section 7).

The quality of *icipe's* research is reflected in its publication record. 871 peer-reviewed papers were published in the period 2013 to 2019 and there was a total of over 13,293 citations over the same period with the annual citation metrics steadily increasing over the whole of this period. The metrics confirm *icipe's* place as a premier research and development Centre in the African innovation system.



Clementine Namazzi, a BioInnovate Africa fellow, carries out her research study under the Programme's project on fungal biopesticides for safe pest control.

Section 5: Vision, Path to Impact and Implementation

icipe's vision over the next decades is to continue as SSA's leading insect research centre, build on its outstanding science and capacity building record, and strengthen the delivery of its research findings to on-ground practice and regional policies for improved health and food security and an improved environment across Africa.

The strategy to achieve that vision can be summarized as:

- a. increasing geographic presence in other African regions
- b. greater attention to project development and implementation for achieving on-ground and policy impacts
- c. a research portfolio which has stronger agroecological approaches, with special emphasis on incorporating social science, and
- d. an expanding commitment to capacity building.

Implementation of the strategy will be via the Centre's own research and development achievements, through its network of partnerships, and will be underpinned by sound governance and financial and human resource management. *icipe* will use its RSIF-PASET program to expand its activities into other regions of Africa through research and capacity building activities in partnership with universities and African ministries responsible for higher education and research. This expansion has already seen *icipe* undertake institutional capacity building in national innovation systems via high-ranking universities in Senegal, Ivory Coast, Nigeria, Ghana and Rwanda, primarily through PhD training under the RSIF-PASET program.

The V&S 2021-2025 delivery pathways are through "New Tools, Technologies Products and Adoption Pathways", "Capacity Development" and "Science-based policy influence" which together will provide outcomes for communities, partnering institutes, stakeholders, regional policies and environment (Figure 2).

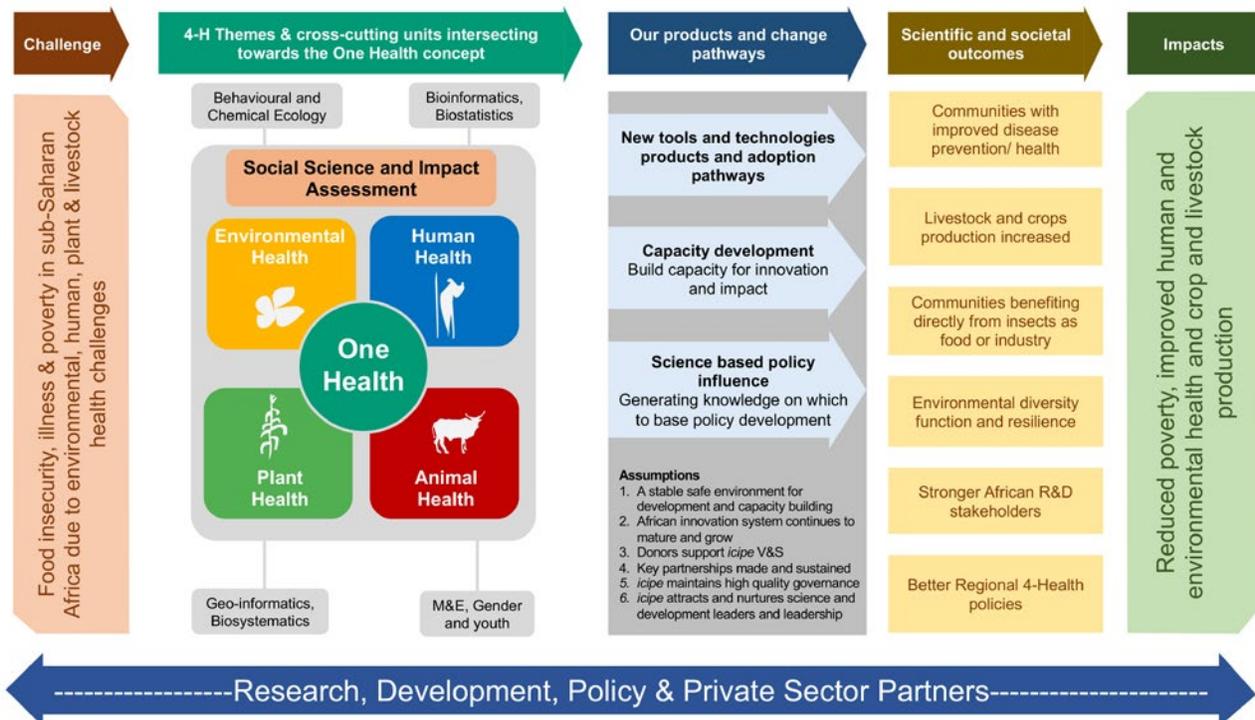


Figure 2. *icipe*'s delivery pathways.

Each of these pathways is important. Finding solutions to existing and new pests and diseases is at the heart of *icipe*'s past successes and that research remains a cornerstone of its strategy. Africa needs to have the capacity to address these challenges with urgency and have the capability to do that at-call. Building capacity for Africa and African institutions is equally important. Africa is 55 countries with extraordinary diversity of environment, culture, wealth, farming systems and language, and *icipe* recognises that interventions in practice or policy must be able to be applied locally to be effective.

***icipe*'s long-term support of the career development of students, scientists and others, and through that, capacity building of national and sub-regional research, development and regulatory institutes and the private sector, has already had impact and will continue to do so.**

pivotal role in developing whole-of-region solutions to challenges across the 4-H Themes and that achieving impact in policy will necessitate active engagement with policymakers and communicating advice in the appropriate ways for those audiences.

To realise this vision, the V&S 2021-2025 incorporates several key actions. The Governing Council will continue its renewal away from a science-dominated membership to a Council with a greater balance from across sub-Saharan Africa, deeper skills in management and governance, and closer linkages to donor, agribusiness, health and private sector networks. New senior administrative appointments are planned in Intellectual Property Management, Human Resources, and Change Management in addition to *icipe*'s goal to migrate to full cost recovery in projects and the need to do more to develop and safeguard its information and communication technology.

icipe already plays an important role in developing science-based policy initiatives but the need for new policies in health, agriculture, animal husbandry, trade, environmental management and urbanisation will almost certainly escalate. *icipe* recognises that its deep knowledge in crucial areas of science can play a

New science positions in systems analysis and modelling and information management and communication technologies are planned. Within the *icipe* research and development teams, there will be a strengthening of the socio-economic capability, a merging of the current Technology Transfer and Social Science and Impact Assessment Units, a stronger PAR paradigm, and commitment to taking research to action, on-ground and/or through policy initiatives.

Whilst *icipe*'s commitment is to respond rapidly to new and emerging insect-based threats and risks through PAR and applied science, the Centre also remains committed to maintaining its strategic research portfolio in recognition of the fact that its past investments in more basic research has fueled the innovations and applications for which *icipe* is known and respected. *icipe* will also continue its recent initiatives towards building greater financial sustainability. It will continue its focus on developing larger strategic partnerships/special programmes with key donors in appreciation of the fact that these partnerships provide longer-term commitment in R4D, financial stability and at the same time assist *icipe* to avoid the dangers of larger administrative, reporting and co-investment demands that occur when portfolios are dominated by large numbers of smaller contracts.

icipe expects to grow its total budget from the average of about USD\$28 million over the past 5 years, to USD\$40M by 2025, with most growth arising from special programmes. That growth will be achieved while maintaining financial reserves of between 4 and 6 months of the Centre's total annual budget. Budget growth will come from increases in both the core and restricted funding components as it is core income that most enables the Centre to operate efficiently and to respond to new challenges of various forms (from exchange rates to new diseases and pests). With that in mind, *icipe* is cognizant of the need to constrain the use of core funding to co-invest in less strategic research so it will continue transitioning towards full cost recovery for each project with the aim of moving from the current position where 30% of projects can be considered as being so costed, to having about >50% of projects in that category by 2025.

Section 6: *icipe* – towards 2025

Commitment to maintain and strengthen *icipe*'s mix of strategic and applied research associated with insect physiology and behaviour that can contribute to control strategies and policies is at the forefront of V&S 2021-2025.

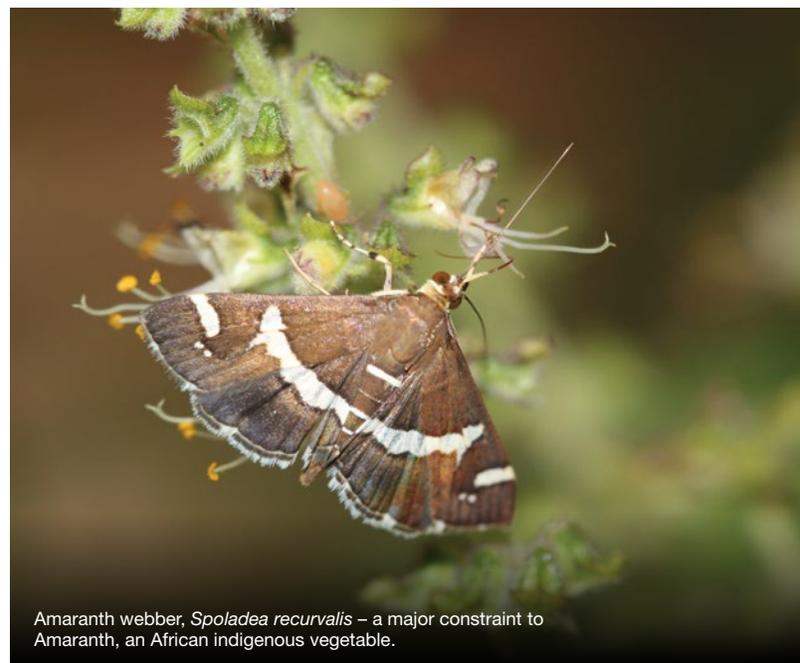
The priorities listed below reflect a mix of continuing with established areas of research, adoption of technologies, livelihood improvement, and new investigations that *icipe*'s science leadership have identified as being of the highest priority based on recognised national and regional priorities and predicted future challenges facing SSA.

Responses to emerging threats and opportunities. A perennial strategy of *icipe*'s has been to remain alert to emerging challenges facing not only Africa, but, more often, issues that are of global concern, and to identify opportunities to use insect science to respond innovatively to such problems. This will continue with special focus on three areas: responses to invasive alien species impacting crop, livestock and human health, the growing role of insects in provision of food and feed, and the accelerating global decline in insect biodiversity.

Alien invasive species and response options: A continuing role for *icipe* across Africa will be that of providing tools and building capacity for early response to new invasive arthropod species. The occurrence of new invasives is increasing, their impacts are often devastating, and given the expectation that trade and travel across Africa and elsewhere will further expand over coming years, it is likely that the frequency at which invasives appear will increase. Some of the more devastating invasive species in recent years have been the fall armyworm (*Spodoptera frugiperda*), a major pest of maize, the South American tomato moth (*Tuta absoluta*), and the Asian blue tick, *Rhipicephalus (Boophilus) microplus*, which has had a devastating impact on cattle and cattle production in West and Central Africa since its accidental introduction in the early part of this century. *icipe* also recognises its potential role in determining biosecurity policies that will need to be strengthened to reduce the occurrence and spread of invasives between countries and subregions in an environment where cross-border trade is increasing. *icipe*

will work with strategic partners to develop, test, implement, and strengthen pest forecasting and early warning systems. The development of data platforms that improve coordination of surveillance and forecasting and are accessible to the user community will be a priority.

Biodiversity and insects decline: The wide use of insecticides, loss and fragmentation of habitats, and climate change are placing multiple threats on insects and related arthropods and their populations are undergoing sharp decline. Loss of habitat in Africa is especially problematic as the yield-gap (the gap between potential and achieved yield) is greater than in other regions of the world and as a consequence, more land has to be cleared to meet the growing demand for food. *icipe* will play an increasing role in attempting to overcome insect decline by intensifying its research on, and supporting the adoption of, innovative methods of pest control that do not rely on agri-chemicals (e.g. biological control options to improve crop and livestock production). It will also undertake research on the impacts of climate change and landscape



Amaranth webber, *Spoladea recurvalis* – a major constraint to Amaranth, an African indigenous vegetable.

connectivity on insect populations where they relate to high priority food production systems. Understanding climate change impacts requires knowledge of insect physiology and phenology and ecological networks that can maintain and improve resilience of the environment affected by insect populations. This type of research is urgently needed if there are to be adequate science-based responses to the concerning decline in insect biodiversity.

Associated with insect decline is *icipe's* continuing research on the health of both African honeybees and native bee populations, the role of symbionts, bee nutrition and pollination effectiveness and their combined impacts in determining resilience and productivity of these species. This research not only aims to build understanding and secure effective pollination of crop and non-crop plant species that are critical for functioning, healthy landscapes, it is also underpins *icipe's* expanding research and development programmes that are providing pathways for women and youth to build enterprises based on bees and honey products (see below).

Insects as food and feed: Africa's rapid population growth and subsequent demand for food will undoubtedly force society to consider new options for feeding livestock and people. This is certainly not a challenge for Africa alone, rather, it is currently at the forefront of research globally and its importance will not diminish. The challenge of feeding people and livestock is being exacerbated by climate change and the need to find options to

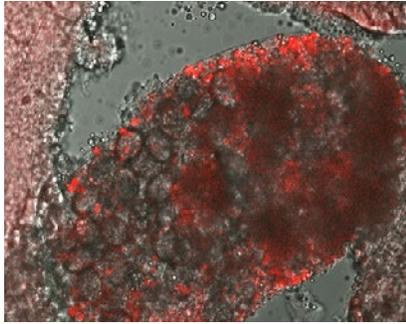
both reduce greenhouse gas emissions, and to adapt to changing environmental conditions. In response, the Centre has established itself as a leader in the globally emerging research on the role insects can have as food, feed and for other uses (Box 14). Insect-based livestock diets are of high quality and in some situations, could be much more cost-effective than traditional animal feed. Also, such diets, especially for ruminants, can reduce methane emissions and in areas where traditional feed options such as forages will be reduced because they are either unable to adapt to new climates or because land use changes preclude traditional feed supply, rapidly-reproducing insect species have the potential to provide alternatives. When it comes to human food, human beings have consumed insects for millennia, and entomophagy, the practice of insect consumption, is carried out by > 2 billion people with ~ 2,000 insect species reported as being used as food.

Based on *icipe's* work to date, Kenya and Uganda have both recognised the need to ready their countries for this new role for insects and have recently become the first African countries to establish official legislation and policy on the use of insects as feed.

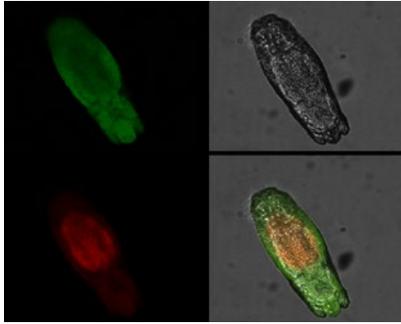
Amongst the basic research priorities is the continuation of *icipe's* **microbiome research** exploring the potential of endosymbionts in making insects more resistant to pathogens and to prevent the transmission of diseases across all Themes. In the Human Health Theme, the focus is on advancing the development of insect endosymbiont-based strategies for the control of vector-borne diseases, which are caused by eukaryotic parasites (e.g. malaria, leishmaniasis and trypanosomiasis) and which exert their greatest impact in Africa. Microbiome research in the Plant Health Theme will build on the current research on endosymbionts of fruit flies and their role and potential use in enhancing IPM strategies, while in the Environmental Health Theme, research on the relationship between honey bee gut microbiota and hive health will be an area for expansion, especially given the rising threats to bees globally (see Box 12).



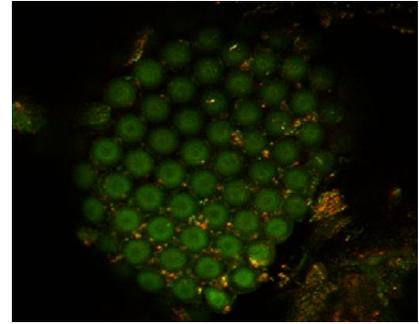
Edible cabbage tree emperor moth caterpillar, *Bunaea alcinoe*.



A) Fluorescence microscopy image overlaid on bright-field image of an *Anopheles* mosquito gut infected with *Microsporidia* sp. by Fluorescence in situ Hybridization (FISH) has been used to stain *Microsporidia* sp. cells (red stain).



B) Fluorescence microscopy image of a developing *B. dorsalis* (fruit fly) embryo. Bright-field channel is grey, green channel is Phalloidin-stained actin and the red channel staining indicates the activation of apoptosis (cell death).



C) Fluorescence microscopy image of sandfly (*Phlebotomus*) ommatidia. The green staining is Phalloidin-stained actin and the red staining is the endosymbiotic bacterium *Wolbachia* stained by Fluorescence in situ Hybridization (FISH).

A parallel priority is in the area of bioinformatics and biotechnology capability in which *icipe* has recently invested significantly. One of the most urgent aims of its genomics research is to build greater understanding of the genetic factors that enable insect species or populations to transmit vector-borne diseases, and especially to explore the potential of using gene editing techniques (CRISPR/Cas9) and other emerging tools to develop appropriate management options (Box 13).

Soil health: The impact of soil biota on soil health is one of the most unexplored frontiers associated with soils. Yet, soil biota, including insects and nematodes, provide many ecosystem services such as pest and pathogen control, maintenance of soil structure and fertility, and carbon and nutrient recycling, which together provide the capacity of the soil to function as a vital living system. Poor soil health remains a key constraint to successful crop production in sub-Saharan Africa. Below-ground pests, such as plant-parasitic nematodes, are ill-researched, yet become important pests under poor agricultural practices. On the other hand, plant rhizospheres and soils harbour an undiscovered treasure of microbes, including endophytes, which may be harnessed to strengthen the plant's natural defenses or for the development of novel biopesticides against below- and above-ground pests. Based on its innovative research on manipulating chemical ecology for nematode control and making available endophyte based IPM tools, *icipe* plans to further expand its scope in soil health research.

Box 13. Arthropod microbiome research is a compelling field that aligns with and strengthens *icipe*'s mission to use insect science for sustainable development. The biology of insects and their symbionts offers a rich scope for finding strategic entry points to reduce disease transmission and control crop pests. Equally interesting and promising is understanding and building on the unique dissemination pathways of some symbionts- such as vertical transmission- that are capable of creating a self-regenerating system of control. *icipe* is becoming a leading institution in the field of arthropod symbiosis in Africa. Since many of the tools and techniques used to study microbial symbionts are shared across the different subject areas, there is enormous potential for synergistic collaborations across all of *icipe*'s themes.

Current research at *icipe* advancing the development insect-symbiont based strategies to control vector borne diseases; in particular of malaria and arboviruses. Microbiome metagenomics as well as targeted molecular approaches, has led to the discovery of diverse insect-specific viruses and endosymbiotic bacteria and fungi of mosquitoes, sand flies, and ticks, some of which appear to inhibit the ability of vector borne diseases to be transmitted by vector arthropods. *icipe* will build on these discoveries and investigate the utility of these symbionts to block the transmission of vector-borne diseases, such as malaria, trypanosomiasis, leishmaniasis, dengue and chikungunya fevers and African tick bite fever initially the laboratory and then in field trials. *icipe* will also continue to develop research on microbial symbionts of crops pests; the Fruit Fly (*Bactrocera dorsalis*) and the Fall Army Worm (*Spodoptera frugiperda*), and symbiotic microbes of the Honey Bee (*Apis mellifera*) that may improve colony productivity. Ultimately, we aim to develop deployable, ecologically sound transmission-blocking strategies based on the endemic endosymbiotic bacteria and/or viruses of arthropod disease vectors as well as new symbiont-based biological control / beneficial insect health enhancement strategies.

Box 14. Biotechnology and genetic methods

Genetic technologies can play an important role in resolving many global problems including poverty, infectious diseases, low agricultural productivity and environmental degradation. The rapid progress of genetic technologies has also raised important questions about potential consequences of these advances. *icipe* is increasingly positioning itself as a leading institute for bioinformatics and biotechnology, with capacity and infrastructure to develop genetic technologies that can contribute to managing pests and disease vectors that affect Africa. In addition, *icipe* recognizes the importance of establishing platforms and approaches for responsible testing of these new technologies. In line with this, the Centre recently constructed an arthropod Biosafety Level 2 experimental testing facility at Mbita Point, for which approval was granted by Kenya's National Biosafety Authority.

The successful implementation of genetic technologies in Africa is dependent on developing the capacity of African scientist to develop and evaluate these tools. *icipe* will continue to lead African capacity building efforts, which includes hosting international training workshops on emerging technologies such CRISPR-Cas9 gene editing and gene drive technologies, along the lines of those that have already been held at *icipe* in 2017 and 2019. There is broad agreement that effective engagement will be required before genetic technologies will be widely accepted in Africa and *icipe* will ensure that from the outset all genetic technology projects engage with communities, local governments and national governments.

Current research at *icipe* is opening up new avenues of research to improve understanding of the genomic factors that predispose some arthropod species or populations to effectively transmit vector-borne diseases of humans, animals and plants, while others do not.

***icipe* will investigate how these discoveries can be exploited through diverse gene editing approaches, to potentially block the transmission of vector-borne diseases to sustainably improve African livelihoods by decreasing the human disease burden and increasing agricultural productivity.**

Box 15. Insects for food and feed

Use of insects as food, feed and oil is recognized as an option for global food and nutrition security and especially protein scarcity, and for providing protein supplements for livestock feed. Insects have an abundance of high-quality protein, micronutrients including vitamin A and B12, riboflavin, calcium, iron, and zinc and as a future major food and feed provide new options to feed people and especially options in overcoming the so-called “hidden hunger”, the lack of protein and micronutrients in diets.

While food security is becoming bigger challenge globally, rising populations and incomes in developing countries are simultaneously driving increases in demand for meat and milk by an estimated 50% from 2005 to 2050. Meeting the demands for more food and feed will require new thinking on how that increase can be sourced, especially the protein components.

Soybean cotton and fish meal are the main source of protein for animal rations with 85% of the world's soybeans being currently processed into soybean cake and oil, and ~ 95% of that used as animal feed. However, feeding animals with proteins from human-edible crops, fish and grains is considered by many as being antagonistic to the notion of achieving human food security. Insect farming and the alternative proteins they produce have a significant role to play in reducing scarcity and improving food and nutrition security. Currently, there is more than 300 insect producing companies worldwide with many start-up companies coming in Africa.

The global edible oils market is expected to increase from \$83.4 billion to \$130.3 billion by 2024 (Persistence market research, 2017) and the primary use for nearly all varieties of oil is in cooking. The growing awareness of food health is having a strong influence on buying patterns and consumers are moving towards adopting more healthy option including omega-3 fatty acids that minimize the risk of chronic diseases but also towards consuming monounsaturated and polyunsaturated edible oils such as peanut oil, olive oil, sunflower oil, and walnut oil as partially hydrogenated oils (PHOs), and cholesterol levels come under increased scrutiny. Currently, the bulk of the edible oils are derived from fruits and vegetables, such as soybeans, palms, sunflowers, and rapeseed. However oil from insects have a significant role to play in filling the growing demand for oil – be it for use as food, biodiesel and cosmetic industries.

Preliminary studies have shown that the amounts of saturated and unsaturated fatty acids they contain are comparable to oils from sesame, groundnut, sunflower, and cottonseed and their oxidative stability is remarkably high in comparison to other edible oils. *icipe* has strategically position itself in the coming years to embark on cutting-edge scientific research on insects to fill global oil demand.

Data management, modelling and geo-information: An expanding area of research will be in the field of metadata analysis. *icipe* possesses data sets associated with insect vector populations and disease occurrence in a range of environments that represent decades of research and investment. These data sets are a resource that has the potential to enable better prediction of future challenges and potential solutions in response to climate change, new invasive species or new vector management strategies. This research area will require considerable strategic investment in data curation, management and storage, including hardware and software to meet the FAIR (Findable, Accessible, Interoperable and Reusable) Guiding Principles for scientific data management and stewardship⁷. New skills including greater modelling and data analysis capability will be required to unlock new data, information and understanding of the many complex interactions associated with pest and disease control, human health, ecology, biodiversity and agricultural productivity.

Enterprise development through Public Private Partnerships (PPP) and youth entrepreneurship: *icipe* will maintain a broad research for development portfolio that simultaneously aims to improve the livelihoods of women and youth through helping them design and operate new small enterprises based on cottage industries.

The principles of this area of research include a requirement for comprehensive understanding of the biology of the insects and the agroecology involved, the existence of locally-accessible markets for products, and the tools and commitment for the training of partners in both the management of the insect resource and in the operation of enterprises. From a research perspective, the critical additional element in this research domain is the social science to enable those factors that most influence the development and sustainability of the small and medium enterprises.

In the immediate future, the focus will continue to be enterprises built on products from the African honey bee and African native bees. An additional

opportunity in enterprise development to be explored over the next five years will be potential for small and medium enterprises based on sourcing high value oils from insects.

Through BioInnovate and RSIF-PASET, *icipe* will significantly increase its efforts to build the entrepreneurial capacity of young scientists and appropriate partnering institutions so that they are better trained and prepared to initiate and support small and medium enterprise development.

One Health: The recognition that more holistic solutions to human, animal, plant and environmental health challenges should be sought through a systems or landscape framework has led *icipe* to seek stronger interdisciplinary approaches to its research via adoption of the One Health concept and integration of the 4-H Themes. The One Health concept is a multi and/or interdisciplinary approach that considers the intersection between human, animal and environmental health⁸ and there are many examples quoted in the literature that especially feature the intersection of animal and human health (e.g. Ebola, Avian flu, Zika). There are far fewer examples of the One Health concept being applied to intersections between human/animal health and environmental health or ecosystem processes⁹. *icipe* seeks to more explicitly add Plant Health to the three traditional components of the concept (Plant Health is traditionally considered within the Environmental Health component of the One Health concept) to ensure a more complete representation of components of the agricultural landscapes in which *icipe* most frequently works and where crops are a crucial element.

The One Health concept has not been tested at an institutional level and *icipe* recognises the challenges of fully incorporating environmental and plant health disciplines and of sourcing funding to explore the opportunities that the One-Health concept can bring to international research and development.

⁷ <https://www.nature.com/articles/sdata201618>

⁸ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4320999/>

⁹ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5816263/>

Notwithstanding these challenges, the impacts of climate change being felt through greater incidences of zoonoses and transboundary animal diseases as well as the impacts of habitat loss, growing populations and ever-increasing demands for food all point to the need for more coordinated, holistic responses across disciplines. *icipe* already has examples of crosscutting research that draws on elements from multiple Themes (push-pull (animal/plant health); Integrated Pest and Pollinator Management (plant/environmental health) and stands committed to build even stronger interdisciplinary framework and systems approach across the 4-H Themes to advance the One Health concept either in full, or through integration of only two or three of the Health Themes if that approach is considered more appropriate. It proposes to do this by assembling and piloting a portfolio of projects that have One Health dimensions and by adding stronger systems modelling, social science, information and communication technologies and engineering science strengths to its skills set.

Strengthening capacity and institutional development: A significant change in the V&S 2021-25 is the expansion of capacity building within *icipe*, especially the expansion into a new role of coordination of pan-African post-graduate training program. The scientific program at *icipe* provides a stellar training environment for the next generation of scholars and scientists, who are poised to address the current and emerging issues in the field of pest management and vector-borne disease control, climate change effects as well as advancing bioprospecting. Over the full duration of the next five years, *icipe* will add to its capacity development portfolio the coordination role of the RSIF-PASET funded by the World Bank, the Government of Korea and participating African states. The selection of *icipe* into this role is in recognition of *icipe*'s track record in post-graduate training and of the quality of its management and governance by regional universities and key donors.



Post-graduate training – expansion of capacity building within *icipe*. L-r: Shaphan Chia (Cameroon), Owusu Aidoo (Ghana), Olabimpe Olaide (Nigeria), Akua Agyakwa (Ghana).

Section 7: Building impact - Scaling up and scaling out

icipe recognises that providing communities with opportunities to make changes in how they live, how they produce and store food, and how they look after their environment requires specialist skills, new knowledge, communication and networks. To achieve this, *icipe* will leverage its past successes to employ a three-pronged strategy to increase its impact and widen its geographic area of influence.

Scaling up: *icipe* will take several measures to better support the uptake of its research. The first of these is to establish a stronger **demand-driven model** to define research and development priorities and to ensure innovations align with end-user expectations. One part of that revised model will be an *icipe*-established Biocontrol Consortium that will have membership from the private sector and other relevant stakeholders. Biocontrol targets (crops, pests and countries) will be jointly identified with the Consortium to ensure biocontrol needs are better informed and prioritised by the end-user. The Consortium will also play an important role in communication on new *icipe* products and technologies, technical training requirements, advising on options for commercialisation of products and providing an influential voice to national and regional policy and regulatory bodies.

A second measure is through project and programme design and implementation being undertaken using a participatory action research (PAR) paradigm. PAR recognises the knowledge of key actors and requires the input of all participants, from researchers to potential beneficiaries. *icipe* will increase the proportion of its applied research projects using PAR, and by doing so, its partners, including those from national and regional innovation systems, will benefit from the wider participatory approach being taken by *icipe*. *icipe* will strengthen its socio-economic skills to enable PAR to be implemented across the Centre, and as previously indicated, the Technology Transfer and the Social Science and Impact Assessment units will be merged to provide a more focused critical mass to enhance adoption of *icipe*'s technologies.

icipe will continue to expand and strengthen its BiInnovate Africa programme, which links new biological-based solutions to end users, including the private sector. Many of the science outputs in Africa fail to advance to uptake because of weak relationships between research and private enterprises. *icipe* has a long history of working with the private sector in delivering many of its discoveries and it will continue, through programmes like BiInnovate Africa, to focus on ensuring that these crucial partnerships are identified and nurtured.

icipe will strengthen its own capacity in communication, and in particular, in communicating its achievements to the many actors who influence adoption of technologies on the ground or in policy. The Centre will make a senior appointment to lead this element of the Centre's communication.

The Centre is already using Information and Communication Technologies (ICT) to support adoption, and will continue doing so with the focus of future efforts being on developing tools and approaches that can use the increasingly ubiquitous mobile phones, especially since a rapidly growing proportion of those phones now being “smart”.

Improving capability: Building on its long experience in post-graduate training in Africa, *icipe* will accelerate its efforts to increase African scientific capability by supporting the strengthening of postgraduate education at African universities. Doctoral-level training, especially for women, and the building of partnerships with the best universities and research institutions globally and with African governments for increasing Africa's own investments in science and ownership, will be prioritised. These will be implemented through the RSIF-PASET initiative to ensure the strengthening

of African scientific institutions that will be the future drivers of the continent's science-led growth. The focus on the PhD level recognises the capacity of African universities in training at the Master's level. Masters will continue to be an important pipeline for PhD training and thus important for increasing Africa's scientific output. *icipe* will initiate these efforts by contributing to a sustainable model for PhD training in Africa.

This expanded commitment to capacity building in Africa provides *icipe* with a pathway to deliver two direct outcomes: Africa benefits from the pool of new scientists making new African-owned discoveries, and African institutions (including universities, research institutions and the private sector) benefit by having access to a better trained and experienced scientists to take up teaching, research or business roles. Together, these direct benefits are multiplied through the next generation of students graduating from an even greater number of universities across Africa.

Indirectly, this capacity building also provides a critical pathway to improved policy outcomes by government and other policy-making agencies having better capability and ability to provide advice founded in science.

Scaling out: In its first 50 years, *icipe* has had a significant R4D presence in East Africa, especially Kenya. However, it recognises that its research capacity is needed to overcome the many challenges across SSA that are relevant to *icipe*'s research portfolio. Since 2013, *icipe* has expanded into Ethiopia substantially, with 29 staff now based there and a further 60-70 positions planned to implement the vastly expanded YESH programme. It has also successfully placed staff in Uganda and Somalia (since closed). As outlined in Sections 2 and 3, *icipe* already has key partnerships with institutions across SSA and believes it can use the lessons learnt from its expansion into Ethiopia, Somalia and Uganda to strategically position itself in other SSA countries where its technologies are demanded. *icipe* will particularly use the RSIF-PASET initiative as an entry point to multiple selected countries in West, Central and Southern Africa. Collaborative partnerships will be established with key universities or other institutions within these selected countries, and it is these partnerships that will form the foundation for *icipe*'s expansion into these sub-regions. The lessons learnt from *icipe*'s previous expansion beyond Kenya has shown that the depth and strength of the institute-to-institute partnerships supported by national and sub-regional agencies are the key to success in scaling out across national borders.

Section 8: Implementation and success: What would the successful implementation of this vision and strategy in 2025 look like?

By 2025, *icipe*'s new vision and strategy will be assessed as successful if it has achieved the following primary goals of:

- (a) Measurable development impacts for rural communities through adoption of new technologies across all the sub-regions of SSA
- (b) Enhanced professional capability being recognised in the RSIF-PASET participating countries as a result of *icipe*'s coordinating capacity building role in that programme
- (c) Evidence that *icipe*'s science has been translated into improved food and nutritional security, biosecurity and health policies for Africa and the tropics in general, and
- (d) *icipe*'s science quality metrics continuing their upward trend and its achievements in its highest research priorities of One Health, microbiome research, insect biodiversity loss and insects as food and feed being recognised as providing new opportunities for Africa's communities and its environment.

To measure both science and development outcomes, *icipe* will invest in both internal and external evaluations and reviews that will provide the evidence for its success, and importantly, the key learning on how *icipe*, as a research for development Centre, can continuously improve lives in Africa and other parts of the world.

List of abbreviations and acronyms

AAIS	African Association of Insect Scientists
AAS	African Academy of Sciences
AIRCA	Association of International Research and Development Centers for Agriculture
ARPPIS	African Regional Postgraduate Programme in Insect Science
Arbovirus	arthropod-borne virus
ASA	ARPPIS Scholars Association
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
AU-IBAR	African Union Interafrican Bureau for Animal Resources
AVDRC	The World Vegetable Center (Shanhua, Tainan, Taiwan)
CAADP	Comprehensive Africa Agriculture Development Programme
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza (Cartago, Costa Rica)
CB&ID	Capacity Building and Institutional Development Programme
CCARDESA	The Centre for Coordination of Agricultural Research and Development in Southern Africa
CFF	Crops for the Future (Selangor, Malaysia)
CIMMYT	The International Maize and Wheat Improvement Center (Mexico DF, Mexico)
CIP	International Potato Centre (Lima, Peru)
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CNHR	Consortium for National Health Research (Nairobi, Kenya)
CORAF/WECARD	West and Central African Council for Agricultural Research and Development
DAAD	German Academic Exchange Service
DRIP	Dissertation Research Internship Programme
EIDs	emerging infectious diseases
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária
EPF	entomopathogenic fungi
FAO	The Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
IAEA	The International Atomic Energy Agency
ICBA	International Center for Biosaline Agriculture (Dubai, United Arab Emirates)
ICIMOD	The International Centre for Integrated Mountain Development (Kathmandu, Nepal)
IDVM	integrated disease and vector management

IFDC	The International Fertilizer Development Center
IFS	International Foundation for Science
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Institute (Nairobi, Kenya)
INBAR	International Network for Bamboo and Rattan (Beijing, China)
IPM	integrated pest management
IRD	Institut de Recherche pour le Développement
ISCE	International Society of Chemical Ecology
IVM	integrated vector management
JKUAT	Jomo Kenyatta University of Agriculture and Technology
LMF	leafminer flies
NARES	national agriculture research and extension systems
NARO	North Africa Research Organization
NARS	national agricultural research system
NEPAD	New Partnership for Africa's Development
NGO	non-governmental organisation
POPs	persistent organic pollutants
R&D	research and development
R4D	Research for development
RBM	Results Based Management
SARS	severe acute respiratory syndrome
Sida	Swedish International Development Cooperation Agency
SSA	sub-Saharan Africa
TRO	Thomas Risley Odhiambo
TWAS	The World Academy of Sciences
UNESCO	The United Nations Educational, Scientific and Cultural Organization
USAID	The United States Agency for International Development
USDA/ARS - CMAVE	United States Department of Agriculture/Agricultural Research Service - Center for Medical, Agricultural and Veterinary Entomology
WB	The World Bank
WHO/AFRO	World Health Organization Regional Office for Africa

For more details about *icipe* and its activities, contact:

International Centre of Insect Physiology and Ecology (*icipe*)

P.O. Box 30772-00100

Nairobi, Kenya

Tel: +254 (20) 8632000

Fax: +254 (20) 8632001/8632002

E-mail: icipe@icipe.org

***icipe* STATIONS**

***icipe* – Duduville Campus**

Telephone number: +254 (20) 8632000

Fax number: +254 (20) 8632001/8632002

***icipe* – Thomas Odhiambo Mbita Campus**

Telephone number: +254 (59) 22216/7/8

Fax number: +254 (59) 22190

Satellite line: +441707657334

***icipe* – Ethiopia Country Office**

Telephone number: +251 (1) 463215

Fax number: +251 (1) 463215



Vision and Strategy

2021-2025

icipe – Working in Africa for Africa

International Centre of Insect Physiology and Ecology (*icipe*) – was established in 1970 in direct response to the need for alternative and environmentally friendly pest and vector management strategies. Headquartered in Nairobi, Kenya, *icipe* is mandated to conduct research and develop methods for pest control that are effective, selective, non-polluting, non-resistance inducing, and affordable to resource-limited rural and urban communities. *icipe*'s mandate further extends to the conservation and utilisation of Africa's rich insect biodiversity.

icipe focuses on sustainable development, including human health, as the basis for development, and the environment, as the foundation for sustainability. Working through a holistic and integrated approach through the 4H paradigm – Human, Animal, Plant and Environmental Health – *icipe* aims at improving the overall well-being of communities in tropical Africa by addressing the interlinked problems of poverty, poor health, low agricultural productivity and degradation of the environment.



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