



meeting the needs
of a changing world:
icipe's vision and strategy
2007 – 2012



African Insect Science for Food and Health

icipe

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**Meeting the Needs of a Changing World:
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2007–2012**

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Foreword

“Only scientific research will bring Africa to a position where it can control its destiny.” Thomas Odhiambo, Founder and First Director General of *icipe*

11 years ago, we released our *Vision and Strategic Framework towards 2020*. At the time, we predicted that the developmental challenges facing Africa were likely to escalate, unless they were addressed. We therefore made a commitment to be part of the solution, bearing in mind the significant roles – both positive and negative – played by insects in the tropics.



Christian Borgemeister,
Director General, *icipe*

In 2003, challenged further by the global issues related to food, health, the environment and poverty alleviation, we revised our vision, using the ‘4H’ paradigm – which encompasses human, animal, plant and environmental health – as the guiding principle of our work. Within this framework, we have made great progress in human health research, where *icipe* scientists managed to push larval control of mosquitoes, which had been neglected for many years, up the research ladder. Moreover, we have created facilities, including well-equipped and well-staffed laboratories, which have become a place of reference for other medical research institutions in East Africa and beyond.

In plant health, we have contributed to the biological control of both indigenous and invasive pests and weeds, which reduced the yields of cereals and horticultural crops throughout Africa. *icipe* researchers and their collaborators devised affordable, accessible, sustainable and environmentally friendly strategies, which are helping thousands of small-scale farmers across Africa improve their livelihoods.

Our environmental health researchers have been working with poor and marginalised communities in Africa to exploit the commercial potential of useful insects, while conserving the biodiversity. The natural products developed through this programme, which include honey and silk, are esteemed in local as well as international markets. Based on the success of this programme in Africa, we have expanded our commercial insects programme to the Near East region.

Given the vital role of livestock in many African communities, *icipe*’s animal health scientists have been working with farmers towards the sustainable control of important disease vectors like the deadly tsetse flies.

In all our efforts, we consider capacity building and institutional development an integral part, and our Centre has continued to contribute to and draw upon the expertise of a range of partners. One of our most successful initiatives is the African Regional Postgraduate Programme in Insect Science (ARPPIS), a partnership of *icipe* and 32 African Universities, through which, by the end of 2006, 190 PhD- and 130 MSc-level African scientists had graduated.

As we move forward in our new strategy 2007–2012, we want to reaffirm the commitment we made 11 years ago, to contribute to the development of the African continent. We intend to build on the achievements we have made so far, and to fine-tune them to global objectives such as the Millennium Development Goals (MDGs).

Our past achievements, our on-going work and our future plans are only possible because of the dedicated support by our Governing Council, the Sponsoring Group of *icipe* (SGI), our donors and a wide range of collaborators from within and outside Africa, which we greatly appreciate.

Christian Borgemeister
Director General, *icipe*



1. Background

Globalisation creates unprecedented new opportunities. However, it does also bear the responsibility for a number of unintended negative consequences. For example, in most developing countries, particularly in Africa, new opportunities for growth and income generation have not been realised. As a result of national and international forces, rural farmers find themselves in a world entirely unlike the one they faced some two to three decades ago. It is in this rapidly evolving context that the majority of Africans, especially the rural poor, need to connect with the benefits arising from better health and education to begin to control the conditions that determine their livelihood. It is also in this regard that science and technology should offer solutions to tackle developmental constraints caused by ill health, food insecurity and environmental degradation.

Established in Kenya in 1970, the founders of *icipe* – African Insect Science for Food and Health, recognised that tropical developing countries had special problems that were not being adequately addressed by scientists and organisations in the North. Furthermore, there was a serious shortage of indigenous expertise to resolve these problems. It should therefore, come as no surprise that *icipe*'s current objectives are essentially the same as they were four decades ago, namely to:

- Help ensure food security and better health for humankind and their livestock;
- Protect the environment;
- Conserve and make better use of natural resources.

But why study insects and arthropods? This is because in the tropics the presence of insects is a fact of life. Insects pose a great risk to food production, often causing loss of entire crops and destroying about half of all harvested food in storage. Also, the 'old' tropical vector-borne diseases—malaria, dengue and kala-azar—are making a dramatic comeback, and frightening new ones are emerging. What is more, livestock succumb in the millions to insect- and tick-borne diseases, resulting in loss of milk, meat and traction power. *icipe* works to improve the well being of the peoples of the tropics (primarily of Africa) through research and capacity building in insect science and its application. This institutional focus has resulted from the realisation that the incidence of pest and disease vectors on the continent is invariably linked to the vicious cycle of poverty and underdevelopment, namely food insecurity, high prevalence

of human and livestock vector-borne diseases, environmental degradation and loss of biodiversity, as well as loss of energy and resources needed for effective productivity.

As the only international institute working primarily on arthropods, *icipe* has a decided advantage in addressing the complex cross cutting challenges above. *icipe's* operative 4-Hs paradigm—addressing human, animal, plant and environmental health and the many integrated pest and vector management (IPVM) and insect-based income generating technologies developed by the Centre over the years, as well as the Capacity Building and Institutional Development Programme —is of immediate relevance to future strategies for contributing to solutions for food insecurity and malnutrition, disease, poverty and environmental degradation.

icipe is about much more than insects. *icipe* also gives attention to agriculture, health and environmental issues. Arthropods (insects, ticks, mites, spiders and others) are at the core of many development problems, especially in the tropics where their numbers and variety are greatest. The problems associated with arthropod pests and disease vectors on the one hand, and the opportunities for their conservation and utilisation on the other – the rich beneficial arthropod resources of Africa are among the most underutilised and threatened – cut across the above three key sectors of health, agriculture and the environment.

Arthropod crop and livestock pests and vector-borne diseases are a major cause of agricultural under-production and poverty. An increase in productivity cannot occur without a healthy workforce, yet many tropical diseases are making a vicious comeback, especially in populations under stress, overcrowding and displacement. Adding to the pest and disease burden are the over-stretching demands on the environment, brought about by farmers too poor to rejuvenate the soil with nutrients or allow a fallow period, and forced to over-harvest forests and natural vegetation for income, thus disrupting nature's regenerative potential.

Overall development cannot be achieved, without advances in technology that is rooted in cutting edge science and in tune with cultural, social and environmental exigencies, refined through appropriate testing and evaluation, then adopted by the target communities.

Mission

icipe's mission is to help alleviate poverty, ensure food security and improve the overall health status of peoples of the tropics by developing and extending management tools and strategies for harmful and useful arthropods, while preserving the natural resource base through research and capacity building. Some of the research directly leads to the development of management tools and strategies, whereas other aspects of the research indirectly feed into this process by enhancing knowledge on harmful and useful insects.

Institutional goals

To achieve its Mission, *icipe* has specific objectives in each of the 4-H research areas of human, animal, plant and environmental health.

BOX 1: Main Institutional Goal

Develop, introduce and adapt new tools and strategies for arthropod management that are environmentally safe, affordable, appropriate, socially acceptable and applicable by the target end-users, with full community participation. Eventually, the outputs of *icipe's* research work will contribute to policy development in areas that are relevant to the Centre's mandate.

BOX 2: Other Institutional Goals

GOAL 1—IMPROVE HEALTH: *icipe* shall provide support of integrated approaches for vector-borne disease control that supplement other efforts such as vaccines and drug development as well as existing vector control tools.

GOAL 2—REDUCE POVERTY: *icipe* shall reduce the impact of arthropod pests that have a direct bearing on poverty, food production and well being; create sustainable livelihoods for rural and peri-urban communities and entrepreneurs through agro-based food, fibre and health products enterprise development and promote use of beneficial insects.

GOAL 3—CREATE KNOWLEDGE: *icipe* shall serve as a regional focus for biosciences and technology information and knowledge, and develop and adapt improved arthropod management technologies.

GOAL 4. BUILD CAPACITY: *icipe* shall build the capacity of individual researchers and institutions in Africa to initiate original research activities as new problems arise; empower women and harness the youth; and build capacity to use, transfer and teach *icipe*'s technologies.

Organisational structure

icipe operates within a management structure based on principles conducive to promoting creativity, diversity and efficiency. *icipe* has also an institutional responsibility for ensuring that the upcoming generations of African scientists have a strong and holistic science-based training within a socio-economic background that is relevant to the needs of the society. *icipe*'s work is organised through the 4-H paradigm, where targeting the improvements in human, animal, plant and environment health have been identified as the most holistic, and cost-effective ways to meaningfully engage with the complex development requirements of African communities and to provide the much needed poverty-alleviating solutions.

icipe's work is carried out under the operative 4-Hs paradigm:

- (a) *Human Health* research contributes to the reduction of malaria and other vector-borne diseases by developing tools and strategies that control the vectors and break the cycle of transmission, and that can be integrated with other disease management efforts.
- (b) *Plant Health* research contributes to improved sustainable food security strategies through the development of integrated pest management (IPM) for field and horticultural crops, and storage pests.
- (c) *Environmental Health* research concentrates on conservation and sustainable utilisation of the agricultural production base and important natural ecosystems by: (i) encouraging and utilising arthropod diversity, (ii) cataloguing and sharing biodiversity data and (iii) discovering endemic wealth by bioprospecting for useful natural products.
- (d) *Animal Health* research aims to increase livestock productivity through development of integrated strategies and tools for livestock vector control, thus leading to greater availability of meat, milk, hides and draught power.

Cutting across the 4-Hs is *icipe*'s capacity building and institutional development activities that work to develop the much needed, well-trained and highly motivated human resource capacity that is able to respond to the arthropod-related development needs of its African constituency. Along with the human capacity is the need to ensure that institutions are in a functioning state and able to bring about the required developmental change.

Feeding into these 4-H themes is disciplinary in-house expertise from important areas such as behavioural and chemical ecology, molecular biology and biotechnology, biomathematics and social sciences. Since all of the activities



contribute to, and are supportive of, the millennium development goals (MDGs), *icipe's* research is development-related, resulting in knowledge-based solutions aimed at equipping the communities to survive and live competitively within a rapidly changing global environment.

icipe has a long tradition of collaboration. Scientists in multidisciplinary teams join forces with the over 80 partner institutions (NRES, NGOs, universities, other international organisations) in Africa and elsewhere in the world in helping set the milestones on the road to sustainable development. On average, about 60 publications annually are produced, mainly as peer reviewed articles in international journals, in addition to annual reports.

icipe has unique facilities which include well-equipped laboratories and office space at its headquarters in Nairobi and field stations with excellent Internet connectivity. The Centre conducts numerous training workshops at the Thomas Odhiambo Conference Centre that has several meeting rooms as well as an international guesthouse with 40 self-contained rooms at the Nairobi campus and another 37 rooms at the *icipe*-Thomas Odhiambo Campus, Mbita Point in western Kenya.

Laboratory work is carried out at the Centre's modern facilities at Duduville, Kasarani on the outskirts of Nairobi and at the main research stations at Mbita Point on Lake Victoria and Muhaka on the Indian Ocean coast. Six other field sites, altogether totalling 500 hectares in Kenya's varied agroecological zones and in Ethiopia and Sudan, provide ample testing ground for validating research output with farmers. Through *icipe's* collaboration with national research systems, a much greater target area and population is reached.

1.1. What makes us unique?

Over its nearly four decades, *icipe* has amassed unique expertise, experience and a record of accomplishments to give the Centre a competitive advantage in solving tropical arthropod-related problems. As an international organisation established in Africa, *icipe* has the advantages of:

- *Being a centre for arthropod research:* *icipe* is the only international research centre working on arthropod research and development in the tropics. It is an independent centre founded in Africa and working for Africa;
- *Using holistic and integrated approaches:* Through the 4-Hs paradigm, *icipe* is helping to improve the total health of a community by addressing the interlinked problems of poverty, low agricultural productivity, poor health and degradation of the environment;
- *Having an outstanding record in capacity building:* Capacity building is conducted, from postgraduate research and training to training of trainers and practitioners, with well-established networks of collaborators and partners in government, national institutions, NGOs and international organisations;
- *Undertaking strategic and applied research:* Some of *icipe's* research leads to demonstrated success in scientific achievement and developmental applications of insect science. The Centre has a successful record of development of several technologies which farmers are using at grassroot levels:
 - Classical biological control focuses on the role and economic value of functional agrobiodiversity in plant protection;
 - Commercial insects' perational models for income-generation from the sale of honey and silk;
 - PAN, a registered plant protection agent for locust control;
 - NGU tsetse traps whose efficacy is enhanced by odour baits, biological control, and use of repellents;
 - 'Push-pull' technology using trap- and repel plants for management of cereal stemborers and parasitic weeds in maize-based farming systems in Africa;
 - Malaria and other vector-borne diseases control by developing tools and strategies to control the vectors and break the cycle of transmission, that can be integrated with other disease management efforts.

icipe is a leading research centre in Africa with a high concentration of well-qualified staff with well matched core competencies in insect science and its application to complement the Centre's mandate and work within the 4-Hs paradigm, for research in:

- Mosquitoes and tsetse;
- Integrated pest management of agricultural and horticultural crop pests and biocontrol of indigenous, invasive and migratory pests;
- Chemical ecology to provide the scientific basis for developed technologies such as for locust control and habitat management;
- Beneficial insects including honey- and stingless bees and silkworms;
- Capacity to integrate agriculture and biodiversity conservation.

1.2. Challenges of the 21st century: The environment in 2007 and beyond

A number of recent scientific advances and global challenges have affected the role of research organisations in meeting their developmental mandates. Ranging from the topical issues in climate change, environmental sustainability of scientific technologies and other emergent concerns resulting from globalisation, they all have strategic implications on how research organisations will respond in meeting the needs of their constituencies. Among the more important challenges that *icipe* must contend with are issues such as:

- *Earth's environment:* The Millennium Ecosystem Assessment has determined that 60% of the Earth's essential ecosystem services have been damaged by human activities. WWF's Living Planet Index, a measure of the Earth's biodiversity, has declined by 30% since 1970. Our Global Ecological Footprint has more than tripled since 1961, and in 2005 exceeded the world's regenerative capacity by almost 25%. Economic growth and development in Africa depend critically on finding environmentally sustainable solutions to its problems and challenges, and on a proper understanding of the values and functions of biodiversity and ecosystem services.
- *Novel climates:* An overwhelming scientific consensus has determined that global climate change is a reality and is largely due to greenhouse gas emissions. Recent analyses, under a business-as-usual scenario, predict that between 12 and 39% of the Earth's land surface will be experiencing novel climates by 2100. By 2085, 25–50% of African plants may have to adapt to such climates or face extinction. Climate change will shuffle the deck of surviving species into entirely new ecosystems and create multiple opportunities for the emergence of new invasive pests and diseases. The consequences for food production and human health are unlikely to be benign, especially in resource-poor tropical countries.
- *Advances in the natural sciences:* Advances in the molecular sciences, particularly in biochemistry and the mapping of genomes, offer many new possibilities for diagnosis and design of new products and applications in agriculture and medicine. For developing countries to be active participants in these research fronts there is a need to share both expertise and technologies, such as those for proteomics, genomics, biotechnology and bioinformatics.
- *Social sciences:* Development is a complex process in which technology development *per se* is not sufficient to bring about change. Social scientists need to make an integral contribution to the design and implementation of research projects and transfer of technology processes. Gender balance and assessment are key and *icipe* research and development activities ensure beneficiaries gain social, economic and environmental advantages from the knowledge generated at the household, village community or global community level.



- *Emergence/resurgence of infectious diseases:* Vector-borne infectious disease still remains a significant public health problem throughout Africa. Arboviral diseases such as yellow fever, dengue, plague, typhus and Rift Valley fever (RVF) are among the re-emerging infectious diseases that pose a global threat. Though efforts have been made to reduce morbidity and mortality due to these diseases, they continue to increase in intensity and geographic coverage because of insufficient action to break the transmission cycle. Climate change has contributed to the resurgence of rare diseases such as RVF in which epidemics that occurred in 1998 and 2006 claimed hundreds of lives in both man and his livestock in East Africa. *icipe* recognises that an increase in productivity cannot occur without a healthy workforce. The Centre, therefore, focuses on improving the health of people so that they can be more active in economic development.
- *Invasive species:* An almost universally recognised downside to globalisation is the spread of invasive foreign species that arises from faster and less restricted travel and trade. New solutions are needed for pests that were once confined to specific latitudes but are now a global threat to farmers, traders, tourists and consumers.
- *New and expanding markets:* New and expanding markets exist for horticulture, special bio- and industrial products from plants and animals, and livestock products. These sectors usually lack the research backup to improve production and meet rigid quality standards. If small-scale producers are to benefit from this increased trade, then trans-boundary diseases and pests need to be controlled and products need to meet international safety and quality standards.
- *Trade and intellectual property rights:* Another aspect of trade of concern (and opportunity) to *icipe* is that of the TRIPS (Trade-Related Aspects of Intellectual Property Rights) and other agreements of the WTO. Relevant, biologically safe solutions to the many new legal health and environmental issues inherent in the biotechnology revolution are needed. The shift of emphasis of transnational agricultural chemical companies into the seed and biotechnology products markets has important social and environmental implications for resource-poor farmers, and international research organisations will need to ensure that their R&D (research and development) results will be available for public use at the lowest possible cost.
- *Access to knowledge and information:* Globalisation, and related open access initiatives, is bringing about an explosion in all kinds of information and access, this being made easier by the IT revolution. The financial implications of keeping on top of the infrastructure required are prohibitive for most LDC (least developed country) institutions, and concern is growing about the 'digital divide'. However, this dichotomy provides an opportunity for making substantial contributions via the medium of partnerships and sharing with local institutions.
- *Synergism in partnerships:* The increasing capacity of national systems, sub-regional organisations (SROs), universities and other collaborators over the last decade has made it imperative that international organisations strengthen their partnerships further.
- *A renaissance and commitment of African governments:* The vast wealth of untapped natural resources challenges the myth of Africa's poverty and the perpetual gloom of the continent's underdevelopment. If managed carefully and sensibly, these resources rekindle the hope for economic transformation and offer a basis for Africa's renaissance. However, the process of Africa's re-awakening and recovery is dependant on the ability of the continent's leadership to recognise that judicious management of the environment and its resources is key for economic development, betterment of livelihoods, peace and national stability. If the African renaissance is to begin to deliver on the economic front, African governments must commit to examine and change their governance structures and policy frameworks in such ways as to encourage critical investments in the judicious management and utilisation of



underdevelopment. If managed carefully and sensibly, these resources rekindle the hope for economic transformation and offer a basis for Africa's renaissance. However, the process of Africa's re-awakening and recovery is dependant on the ability of the continent's leadership to recognise that judicious management of the environment and its resources is key for economic development, betterment of livelihoods, peace and national stability. If the African renaissance is to begin to deliver on the economic front, African governments must commit to examine and change their governance structures and policy frameworks in such ways as to encourage critical investments in the judicious management and utilisation of

these resources. Any shortfall in the governments' commitment in this regard would lead to an erosion of the natural resource base and herald a slide into an ever-deeper poverty level.

These challenges will be at the core of the development agenda of the African continent in the next decade or so. *icipe's* unique evolution as an African institution and its institutional commitment in pursuing a development agenda for the benefit of Africa's poor means that the Centre must develop an institutional mechanism to respond to them. The strategic response will comprise of knowledge-derived components, mostly scientific, that *icipe* and similar mandated institutions are best placed to develop and deliver. However, the scientific responses will need to be underpinned by a number of enabling components, such as policy environments put in place by the African leadership. In essence, these challenges will need forging of new partnerships, between institutions and organisations, and with governments in both national and regional fronts. The complexity of these challenges will require integrated solutions resulting from multidisciplinary partnerships. This type of approach is not new for *icipe*.

1.3 Highlights of progress — Milestones from *icipe's* 2007–2009 MTP

In human health, fundamental studies of the ecology and behaviour of mosquitoes and tsetse flies are yielding new opportunities for control. These studies include:

Conducting operational research on ecology and behaviour of mosquitoes and malaria epidemiology: Studies conducted in a number of eco-epidemiological zones in Kenya and Eritrea have led to a better understanding of mosquito vector ecology and behaviour, leading to targeted applications of control tools. The ecology of larval stages of vector mosquito species has been extensively explored in the different ecological zones, including highlands, rice systems, urban and lake regions, and coastal areas leading to a better understanding of the application of larval control strategies. In these areas, larval habitats have been mapped with an indication that more than 90% are man-made. Larval control, which has been neglected for many years, is now being considered for re-introduction in the disease control programmes.

Implementing integrated vector management (IVM) demonstration projects for malaria control in different ecosystems in collaboration with national malaria control programmes and local communities: Participatory approaches instituted within the different projects have seen tremendous improvements in delivery and uptake of control tools at community level leading to a considerable reduction in malaria burden. The involvement of the communities and other local stakeholders and the use of environmentally friendly vector control tools such as environmental management, *Bacillus thuringiensis israeliensis* (Bti), screening and use of long-lasting insecticide-treated nets have helped to substantially reduce mosquitoes and malaria within a short period.

Training of Trainers as community vector control specialists in collaboration with WHO/AFRO: *icipe* hosted a number of regional workshops and training sessions on IVM with support from WHO/AFRO and UNEP. This has led to improvements in malaria control capabilities and networks within the African region. As a WHO Collaborating Centre on IVM, *icipe* plans to provide technical information to countries in Africa to effectively control vector-borne diseases.

Identifying chemical signals that Anopheles gambiae use to locate humans: *icipe* scientists have evaluated different blends of 11 constituents of human foot odour (identified by GC-EAD, GC-MS and GC co-injections with authentic samples) in semi-field setting in a screen house. Seven to eight constituents were found to be part of the attractant blend and three were part of the repellent blend. The relative amounts and proportions of the two determined the degree of attraction of a given foot



odour. The counterflow geometry (CFG) trap baited with the attractant blend also performed significantly better than the bednet trap with human bait and the CDC light trap. Large variations in the attractiveness of human breath were found in two-choice assays in a wind tunnel. Both carbon dioxide and minor breath constituents were found to mediate long-range attraction of mosquitoes. GC-EAD analyses have indicated the presence of 15 electrophysiologically active minor constituents that are currently being evaluated in the greenhouse.

Determining the factors that underlie oviposition selection behaviour of malaria vectors: Oviposition by *A. gambiae* was found to involve both active avoidance ('push' effect of unpreferred pools such as those preferred by culicine mosquitoes) and attraction ('pull' effect), both mediated by volatile semiochemicals. Interestingly, oviposition in preferred pools was regulated by conspecific larval density. Moderate densities enhanced their attraction (a volatile pheromone was implicated) while high densities deterred further oviposition.

Elucidating mosquito–plant relationships: A survey on plant-feeding behaviour of mosquitoes has revealed that *A. gambiae* mosquitoes prefer to feed on certain plants while they tend to avoid others near larval breeding sites and human dwellings. Some of the preferred plants may be sources of sugar meals or secondary plant metabolites that have a negative impact on parasite development in the mosquito guts. Further studies are ongoing to establish the epidemiological significance of these findings.

Enhancing capacity in bioinformatics: Two PhD and one MSc students were trained in bioinformatics in South Africa, USA and Mali. They have established collaboration with institutions that have notable expertise in this area of research. The *Anopheles* genome was recently completed and gene mining is a new approach of identifying novel target sites for arthropod management.

Identification of malaria vectors using PCR-based assays: icipe has a well-equipped and staffed laboratory for identification of field-collected mosquitoes and in this respect has become a reference laboratory for other medical research institutions in East Africa.

Studies on vectors of human African trypanosomiasis: Development of baits for riverine tsetse, vectors of human sleeping sickness are in progress.

In plant health, icipe has utilised three approaches to manage important plant pests. These are:

(a) Biological control approach for the management of introduced pests:

Stemborers: The economic benefits of over 20 years of R&D work on the biological control of stemborers, have been estimated at US\$ 183 million for Kenya alone and at \$1.8 billion for the East and Southern Africa (ESA) region.

Diamondback moth (DBM): Two parasitoid species were introduced and released in East Africa. DBM has since ceased to be an economically important pest in highland growing conditions. Also, substantial control was achieved in mid-altitude semi-arid areas. Insecticide use in crucifer production has now decreased significantly.

Red spider mite (RSM): Surveys for natural enemies of this invasive pest in Brazil have yielded a promising predatory mite, that is to be introduced to Kenya and will be released in 2007 in pilot areas. Resistance screening and crossing of wild tomato species with commercial varieties should produce highly resistant breeding lines.

Leaf miner flies: Three candidate parasitoid species for biological control of leaf miners in Africa were identified in Peru, and another species in China.

Fruit flies: Fruit fly management materials based on bait-based technology and locally developed *Metarhizium anisopliae*-based mycoinsecticide



were identified and field-tested. Application of the control package reduces fruit fly damage, minimises fruit rejection by the export market, and results in a decrease in the use of insecticides.

Larger grain borer (LGB): Molecular tools, prerequisites in release and follow-up studies of biological control programmes, were developed for identification of different geographic races of the LGB's predator *Teretrius nigrescens* adapted to different climate conditions.

(b) Habitat management approach for the management of cereal stemborers and parasitic weeds

Push-pull: More than 10,000 farmers have adopted the 'push-pull' technology in eastern Africa for the control of cereal stemborers and parasitic weeds. A five-year economic analysis shows a six times greater gross benefit and more than a three times higher return on labour with push-pull than with conventional farmers' practices.

(c) Semiochemical approach for the management of locusts

Desert locust: Large-scale trials in the Sudan confirmed the efficacy of the adult pheromone constituent PAN to control hoppers with or without fractional doses of bio- and chemo-pesticides. PAN has now been officially registered as a plant protection agent for locust control in the Sudan.

In environmental health an increased understanding of ecology and biodiversity has opened up better ways of utilisation and conservation. Among the key outputs are:

Biodiversity conservation: *icipe* has become one of the lead institutions in CI/CEPF conservation investment in the Eastern Arc Mountains and East African Coastal Forests Global Biodiversity Hotspot.

Commercial insects research: Key areas have been in: (i) livelihood improvement in communities adjacent to key forests in Uganda, Kenya and Tanzania; (ii) establishing a portfolio of the ways in which forest insects can benefit adjacent human communities (currently worth > \$100,000 per annum at one site in Kenya); (iii) commercial insect initiatives (apiculture and sericulture) established and supported in 24 countries in Africa with over 7500 farmers and 867 extensionists trained; and (iv) research and development of technologies for utilising wild and domesticated bees and silkmooths.

Stemborers of wild grasses: Increased understanding, in collaboration with IRD, of the ecology and evolution of stemborers of wild grasses.

Participation in FAO's Global Pollinator Initiative: Research initiated into the role of forests as reservoirs of crop pollinators.

Insect database development: Development, in collaboration with the Smithsonian Institute, of electronic databases for African insect biodiversity.

Natural products development: Collaboration with Diversa and DuPont in bioprospecting for industrial enzymes and pest control products under an International Property Rights (IPR) agreement with KWS. This has led to development and refinement of three natural products (Naturub, Mozigone and Mondia tonic).

Establishment of a live butterfly exhibit: Collaboration with the National Museums of Kenya to develop a live butterfly exhibit as an ecotourism attraction, educational and awareness facility, and market outlet for coastal forest butterfly farmers.





In animal health, the development of repellents and traps has paved the way for effective control of livestock vectors. Among the measures developed are:

Development of tsetse repellents: Two types of repellents were identified for reducing tsetse challenge, disease incidence and drug use. These repellents were developed from synthetic equivalents of natural repellent blends from unpreferred animals like the waterbuck, or by molecular optimisation of existing natural repellents found on body odours of tsetse bovid hosts (Patent No. KE00185).

Concurrent use of odour-baited traps and repellents (push-pull): This has been shown to represent a more efficient way of tsetse suppression and disease reduction. Dispensers for the identified potent waterbuck repellent blend are being developed. Production of synthetic repellent was undertaken in-house and this provided an opportunity to transfer the process to potential entrepreneurs for commercialisation. Pastoralists and other farmers show a high preference for *icipes* repellent technology even though it is still a prototype.

Tsetse trapping: In Ethiopia the well-established NGU trap, particularly suited for savanna species, is used in an adaptive management approach. This includes utilisation of GIS technology to identify 'hot-spots' of high tsetse fly densities for strategic deployment of traps to improve efficacy of trapping. For long-term sustainability, communities are involved at every stage of the control operations — from planning to construction of traps to monitoring and evaluation. Community-based tsetse trapping was also being undertaken in the interface between agricultural land and game reserve to reduce human/wildlife conflicts through effective tsetse control and improvement of livestock health and productivity.

Epidemiology of trypanosomosis: Considerable progress has been made in the understanding of the epidemiology of trypanosomosis and associated genes. Characterisation of odour-binding proteins and receptors of tsetse was in progress for development of more potent repellents and attractants.

On-farm tick management strategies: Ethno-botanicals and pathogens have been identified for development of simple on-farm tick management strategies based on behaviour manipulation.

Capacity building: Several postgraduate students, and technicians and farmers from different African countries have been trained to ensure sustainability of vector control activities.

***icipes*'s capacity building and institutional development activities lay emphasis on 'hands-on' experience and regular contact with the target communities. The programme is structured along the following major thrusts:**

- (a) **Training at the postgraduate level:** Postgraduate training, both at doctoral and masters levels, is provided through the African Regional Postgraduate Programme in Insect Science (ARPPIS) and the Dissertation Research Internship Programme (DRIP).
 - ARPPIS is a flagship network activity coordinated by *icipes*. The ARPPIS network was established in 1983 by *icipes* as a partnership programme with African universities, to provide young African scientists with the opportunity to study and learn in Africa, about the insect pests and vectors that are a threat to the health and sustenance of the African people and which limit the continent's development. The network draws upon the expertise and resources of both the universities and *icipes* and is composed of two major programmes: the ARPPIS Sub-Regional Masters Programme (hosted by three collaborating universities in different sub-regions in

Africa—Western in Accra, Eastern in Addis Ababa and Southern in Harare and the ARPPIS Regional Doctoral Programme (hosted at *icipe*). The membership of the ARPPIS participating universities has risen from 28 in 1983 to the current 32. The new members are Gulu University (Uganda), North West University (South Africa), Maseno University (Kenya) and University of Mauritius.

- *The ARPPIS Regional Doctoral Programme* is a 3-year doctoral programme hosted at *icipe*, which enrolls an average of 7–8 PhD research scholars annually who undertake thesis research in various arthropod and insect science-related topics within the 4-Hs research areas. Since its establishment, ARPPIS has to date trained over 190 PhD- and 130 MSc-level scientists from 29 African countries. ARPPIS training has been a model for postgraduate education, especially since most of its trainee-output has remained in Africa pursuing the careers they were trained for. Since 2003, a total of 38 PhD students have been trained (human health 3; plant health 21; animal health 5; and environmental health 9).
 - *The ARPPIS Sub-regional Masters Programme* is a 2-year masters programme undertaken at sub-regional level, hosted by selected participating universities and provides graduate research training leading to award of MSc degrees. The programme consists of one year of taught coursework followed by one year of independent research and thesis preparation. Since 2003 a total of 41 MSc scholars have been trained within the sub-regions at the following universities: (Addis Ababa 3; Ghana 35 and Zimbabwe 3).
 - DRIP is an *icipe* programme that enables postgraduate research scholars undertaking studies in tropical insect science from universities in both developed and developing countries to access the Centre's state-of-the-art research facilities. DRIP facilitates and enhances *icipe's* collaboration with universities and other centres of excellence in these countries, for interactive technology development and exchange, as well as for enhancing the capacity and productivity of African universities by availing to them advanced research facilities and resources for collaborative research and training. Between 2003 and 2006, the DRIP programme trained a total of 45 PhD and 58 MSc scholars. These were spread as follows human health: 13 PhD, 18 MSc; plant health: 14 PhD, 16 MSc; animal health: 8 PhD, 9 MSc; and environmental health: 10 PhD, 15 MSc.
- (b) **Technology dissemination to NARES** through group training courses through a Trainer of Trainers (ToT) approach ensures that the technology dissemination and uptake process is facilitated by a well-informed cadre of national scientists from various institutions in Africa. Since 2003, a number of Group Training Courses has been carried out in different thematic areas. For example, an international training workshop on the Conservation and Utilisation of Commercial Insects was held in November 2006 for some 34 participants from 20 African countries. Since 2003 a total of 51 courses have been held through collaborative participation of *icipe* and partners. These are distributed as follows: human health: 7; plant health: 25; animal health 3; and environmental health: 16.
- (c) **Professional development schemes** promote research interaction and networking through visits and exchange programmes that provide opportunities for both young as well as established scientists, including university faculty worldwide, to share and contribute to *icipe's* research agenda. Such professional upgrading opportunities are carried out through Postdoctoral Research Fellowships (PDF), Visiting Scientists', and Research Associates' schemes. Through these schemes, *icipe* programmes have hosted some 25 scientists since 2003.
- (d) **Interactive on-site training** assures end-user participation and ownership of the technology alternatives being made available through formal, two-way consultation and



awareness-building courses, field demonstrations and open days, undertaken at regular intervals in close partnership with the communities that *icipe* works with. Through these forums, practical technological packages are disseminated in response to farmer needs in diverse areas such as fruit fly baiting, tsetse trapping, elimination of mosquito breeding habitats, management of cereal stemborers and control of the parasitic striga weed, and in the promotion of income-generating livelihoods based on silkworm rearing and honeybee keeping. Through these avenues, more than 16,000 farmers from 24 African countries have been trained and the numbers keep growing each year.

- (e) **Fostering Africa-wide cooperation and networking** ensures that a pan-tropical presence of *icipe*'s work is achieved through vibrant networking and outreach programmes. Through the ARPPIS Scholars Association (ASA), the alumni foster close collaborative linkages with the Centre's research and training work, and provide mentoring for trainees-in-residence. The African Association of Insect Scientists (AAIS) provides a continental platform for exchange of information and experiences with peers working in Africa. Both ASA and AAIS have held biennial meetings since 2003. *icipe* provided expertise and backup for the development of the ASA strategic plan in 2006. *icipe*'s Information Resource Centre has been established as an information hub for collaborating universities and institutions throughout Africa, providing access to both print and electronic content for reference purposes.
- (f) **Institutional** development through nurturing and strengthening of African organisations and institutions, both formal and informal, to mainstream the technology uptake process, facilitate upscaling and outscaling (in both production and market related aspects), is vital if research is to impact on socio-economic development of the African people. Seven ARPPIS universities have benefited from increased online info-access through a UNESCO-supported programme negotiated by *icipe* on their behalf. The three ARPPIS MSc Sub-regional Centres have also benefited from support for equipment like computers and literature access.



2. *icipe* within the context of the MDGs

The millennium development goals (MDGs) represent a global partnership that has grown from the commitments and targets established at the world summits of the 1990s. Responding to the world's main development challenges and to the calls of civil society, the goals aim to promote gender equality and empower women, eradicate extreme poverty and hunger, achieve universal primary education, improve maternal health, ensure environmental sustainability, reduce child mortality, combat HIV/AIDS, malaria and other diseases, and develop a global partnership for development. In general, the MDGs commit the international community to an expanded vision of development, which promotes human development as the key to sustaining social and economic progress throughout the world. Recognising the importance of creating global partnerships for development, MDGs have been commonly accepted as a framework for measuring development progress in the 21st century.

Over 60% of people living on less than one dollar a day live in rural areas, and more than 70% of the labour force in low-income countries work in agriculture. Hunger and starvation are a daily reality for more than 842 million of the world's poorest people. Furthermore, by 2050, the world population will be 9 billion, up from 6 billion in 2007. Food demand will double and water use will increase by 50%. If we are to eradicate poverty and have any chance of feeding future generations, we must improve agricultural productivity and rural incomes. The first seven goals are mutually reinforcing and are directed at reducing poverty in all its forms. The last goal—global partnership for development—is about the means to achieve the first seven goals (realised in partnership with the developed countries). *icipe*'s research and development activities greatly contribute to these MDGs as shown below.

BOX 3: How *icipe's* research and development activities contribute to the MDGs

GOAL	<i>icipe's</i> R&D CONTRIBUTION
GOAL 1: Eradicate extreme poverty and hunger.	The ultimate goals of <i>icipe's</i> research are to reduce the impact of arthropod pests that have a direct bearing on poverty, food production and well-being; create sustainable livelihoods for rural communities and entrepreneurs through agro-based food, fibre and health products enterprise development and promote use of beneficial insects. The Centre develops solutions to the problems of the peoples of Africa that are appropriate, affordable, accessible and acceptable. <i>icipe's</i> tangible end products—honey and silk—are vital components of household coping strategies. The products from the technologies are a source of cash to be sold when food supplies run short or illness strikes a member of the household.
GOAL 2: Achieve universal primary education.	Arthropod research plays a major role in underpinning education. Throughout Africa, school fees is frequently funded by crop and livestock sales. Better crop and livestock productivity through the Centre's activities also means better nutrition for the rural children. Better-nourished children are better able to attend school and an adequate protein intake enhances their ability to learn. Poor health is a reason for non-attendance at school, which is why contributing to the control of a long, chronic and difficult to diagnose disease such as malaria is an important component of ensuring access to primary education for all.
GOAL 3: Promote gender equality and empower women.	<i>icipe's</i> efforts to promote its research and development projects in the context of sustainable rural development have always included a gender issues component, ensuring that women's role in food and livestock production is considered and that measures are in place to ensure that they have full access to project benefits and are involved in community planning exercises. Key examples include: (i) development of a methodology for community participation of women in pest and vector management; and (ii) community-based management and comprehensive training programmes for women farmers.
GOAL 4: Reduce child mortality and GOAL 5: Improve maternal health.	Researching the arthropod related problems also means directly focusing on human health by controlling human diseases like malaria and African sleeping sickness that are being addressed by <i>icipe</i> . Through <i>icipe's</i> mission and institutional goals, the Centre develops, introduces and adapts new tools and strategies for arthropod management that are environmentally safe, affordable, appropriate, socially acceptable and applicable by the target end-users, with full community participation. Controlling vector-related diseases helps empower women by adding income that helps support maternal health and reduces child mortality. In addition, <i>icipe's</i> research in vegetables and fruits boosts health and also contributes to nutritional value and higher income.
Goal 6: Combat HIV/AIDS, malaria and other diseases.	Vector-borne diseases remain a significant public health problem throughout SSA. Diseases such as malaria, leishmaniasis, human African trypanosomosis, onchocerciasis and schistosomiasis are among the most prevalent parasitic diseases. In addition, some arboviral diseases such as dengue, yellow fever and Rift Valley fever are among the re-emerging infectious diseases that pose a threat globally. <i>icipe</i> recognises that an increase in productivity cannot occur without a healthy workforce. The Centre focuses on improving the health of people so that they can be more active in economic development. In addition, livestock diseases are key research health areas in <i>icipe</i> particularly in tsetse/animal African trypanosomosis research and control.
GOAL 7: Ensure environmental sustainability.	<i>icipe's</i> environmental health research focuses on conserving threatened habitats and species through education and sustainable utilisation. The Centre has several research and training activities that deal with inventorying, conservation and utilisation of biodiversity. Environmental health activities started with the silk and beekeeping projects and have now been extended to include the environmental impact of genetically modified organisms (GMOs), the contribution of arthropods to ecosystem services ranging from soil biota to pollinators, and bioprospecting for medicinal plants and other income-generating products for insect control and other uses. There is an active programme of education and outreach related to practical biodiversity, including farmers' courses (Farmers Field Schools) and postgraduate training programmes in collaboration with several universities in Africa and other parts of the world. Finally, <i>icipe</i> searches for and develops environmentally safe integrated pest and vector management options that eschew the use of pesticides and synthetic chemicals wherever possible.
GOAL 8: Develop a global partnership for development.	This eighth goal includes steps that developed countries need to take in support of the campaigns of developing countries to win the first round in the fight to ultimately eradicate poverty (that have an impact on aid, debt, trade, jobs for youth and access to disease fighting drugs). Since its establishment, <i>icipe</i> has relied on various forms of collaborative and networking arrangements in order to fulfill its programme and institutional objectives. The partnerships have been formed at the national, regional and the global level. <i>icipe's</i> approach to forming partnerships begins with taking stock of the comparative advantages within the various institutions. <i>icipe</i> then purposefully cultivates and nurtures the collaboration in a way that will enhance the output and effectiveness in realising its strategic goals. Various forms of linkages have been developed with international agricultural research centers (IARCs), regional and national R&D systems, advanced laboratories as well as universities.





3. Strategic implementation—Focus on *icipe's* 4-health themes as well as capacity building and institutional development

3.1 Human Health

(a) Overview of activities

Vector-borne diseases remain a significant public health problem throughout SSA. Diseases such as malaria, leishmaniasis, human African trypanosomosis, onchocerciasis and schistosomiasis are among the most prevalent parasitic diseases in SSA. In addition, some arboviral diseases such as dengue, yellow fever, chikungunya, plague, typhus and Rift Valley fever are among the re-emerging infectious diseases that pose a threat globally. *icipe* recognises that an increase in productivity cannot occur without a healthy workforce. *icipe* human health research therefore focuses on improving the health of people so that they can be more active in economic development. Since the 1970s, little attention has been given to vector control, which has resulted in a dramatic decrease in human and financial resources in many countries in Africa. However, a series of significant events over the last decade have underlined the growing interest and commitment to stepping up efforts to control these diseases. In 2001, the World Health Organization (WHO) launched the Roll Back Malaria (RBM) Partnership, the main goal of which is to reduce mortality due to malaria by half by the year 2010. Recently, efforts by other foundations and the US President's Malaria Initiative are indicative of the (hitherto unknown) support and goodwill from donors and political Africa, and have now paved way for both the research community and implementing bodies alike to make an improvement in Africa's disease burden.

The support of an integrated approach for vector-borne diseases will supplement other efforts such as vaccines and drug development as well as existing vector control tools. *icipe* is contributing to an IVM-approach by developing environmentally friendly tools and strategies to control the vectors at all life-stages, including the use of botanicals like neem and biopesticides like *Bti*, biological control and attractants identified from preferred plant/human/animal hosts, while at the downstream research end, we involve the communities to be aware of the problem and break the disease transmission cycle.



(b) Goal and broader objectives

icipes R&D activities in human health contribute to the reduction of malaria and other vector borne-diseases by developing tools and strategies that control the vectors and break the transmission cycle, and which can be integrated with other disease management efforts. The broader objectives are to: (i) contribute to the national disease control programmes by focusing on the ecology and behaviour of arthropod vectors; (ii) strengthen linkages and networks with national research and teaching institutions in Africa; (iii) develop integrated vector management strategies for use in different ecological settings; and (iv)

contribute to the WHO/AFRO initiative of strengthening vector control capability for the national disease control programmes in Africa.

(c) Strategic future plans (to 2012)

Develop capabilities for monitoring and evaluation of interventions, and control strategies of vector-borne diseases in SSA: Monitoring and evaluation is an integral part of the vector control strategy. However, capacity and structural framework for institutionalising it in vector control programmes in Africa is lacking. *icipes* hopes to take a lead role in strengthening co-ordination of a collaborative network of institutions and programmes across Africa to capture available data from key sources to guide control decisions. Networks and capacity will be strengthened in national disease control programmes at different levels for data collection and management, monitoring vector populations, infectivity, and insecticide resistance management. Focus will be given to factors that drive seasonal variability in disease endemicity in different ecological settings in Africa. Although the dry season characterises most of the tropical areas of Africa, virtually nothing has been recorded about the influence of the dry season on malaria vector population dynamics in relation to transmission intensity.

Conduct research leading to development of new and improved vector control tools: Vector control across Africa has been compromised by reduced efficacy of existing tools partly due to emergence of insecticide resistance and lack of functional institutional framework and capacity for the implementation of existing ones. A search for new tools remains a high priority for *icipes*'s R&D. In this effort, *icipes* will develop new tools for sustainable integrated vector control programmes in SSA. One area of interest emanating from studies undertaken to date at *icipes*'s R&D is the observation that adult mosquitoes have specific plant feeding preferences. Incorporating biological control agents and insect growth regulators (IGRs) with the mosquito-preferred plants as bait or delivery target would be a novel method for vector control.

Capacity building within the existing study sites, expansion of activities in other regions and continuing education of African vector control specialists: The current decreased efficacy of control measures could to some extent be attributed to technical and operational issues related to acute shortage of personnel with skills and time to provide decisions on vector control at the level of programme implementation. Although past capacity building efforts across Africa had aimed at producing skilled personnel for control programmes, only a small proportion plays an active role in vector control. It is on this basis that *icipes* has a focus of training skilled personnel tailored to institutional needs of respective national disease control programmes. The training will aim to enhance skills and knowledge in control and prevention of vectors, and enhance skills for utilising such knowledge, resources and tools to sound decision making to prioritise disease prevention and control strategies.

Establish malaria early warning system in epidemic prone areas by coordinated data collection and surveillance at selected sentinel sites in SSA: Epidemics of malaria and the neglected tropical diseases occur periodically in many parts of Africa as a result of a complex of biological,

environmental and climate anomalies resulting partly from environmental degradation and the challenge of global warming. It is estimated that at least 110 million Africans live in regions prone to epidemics, and many more are potentially at risk. Because of low levels of immunity among these populations, the risk of death is high, in all age groups, when epidemics occur. Improved early warning and detection of disease epidemics remain among the key technical elements of the national disease control programmes. *icipé*, working with partners, aims to improve access to information on climate and environmental variability that could help affected countries plan and respond to disease epidemics more effectively. This will help to inform disease control programmes of changes in epidemic risk in countries or regions where epidemics are a significant or potential public health problem to make informed decisions.

New initiatives on interactions between agriculture and malaria: Initiatives in agriculture and health are often pursued in a parallel and unconnected fashion. Yet coherent, joint action in agriculture and health could have large potential benefits and substantially reduce risks for the poor. There is growing recognition that agriculture influences health and vice versa, and there is need to take advantages of these linkages to improve food security and health. *icipé* will facilitate new initiatives on interactions between agricultural activities in Africa and South East Asia and malaria with the goal of building sustainable partnerships for improved agricultural production and health.

Identify novel target sites for arthropod management, including biorational pesticide compounds, attractants and repellents detrimental to disease-causing vectors: Capacity in genomics and bioinformatics will be increased for greater integration of these disciplines into R&D and capacity building programmes. For instance, work on genomics will enable identification of novel target sites for biorational development of attractants and repellents, and species-specific biocides. This capacity will also improve taxonomy, allowing more accurate identification of species within complexes, such as *Anopheles gambiae*, the major vector of malaria in Africa, and enhance species identification in biocontrol programmes.

Expand the human health activities to cover not only malaria, but also other arthropod-borne diseases, including emerging infectious diseases: While arthropod vectors such as mosquitoes, tsetse, ticks and sandflies are responsible for the natural transmission of most parasitic and viral pathogens to humans, the threat of these pathogens as potential emerging infections is real mainly because of their extreme infectivity and the favourable conditions for their transmission in Africa. Good examples are Rift Valley and dengue fevers. Global demographic, climate and societal changes, and modern transportation have provided the mechanisms for these pathogens to break out of their natural ecological niches and become established in new geographic locations where competent arthropod vectors and a large population of non-immune hosts provide permissive conditions for them to cause major epidemics. The strategy is designed to focus on the natural history of arthropod-borne diseases in Africa and to investigate the relationship of their zoonotic cycles based on landscape ecology, to develop risk models for simulation elsewhere.

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

Conduct research leading to better understanding of the epidemiology and control of leishmaniasis in Africa: Visceral leishmaniasis is often underestimated while mortality can reach as high as 90% if untreated. *icipé* will lead a network of collaborators in conducting research leading to

better understanding of risk factors associated with the transmission of the disease as well as to undertake studies on the biology of the vector and its control. This is intended to be an integrated project bringing together experts from different African institutions, and institutions in the West, through the coordination of *icipe*. Other initiatives include the development of a system for delivery of entomopathogenic fungi (EPF) conidia into termite mounds and animal burrows for control of sandflies. Studies undertaken to date in *icipe*'s R&D show that injection of conidia of EPF into termite mounds successfully kills termites. Since sandflies inhabit eroded termite mounds and animal burrows, a device similar to the one developed for termite control could be adapted for sandfly control.

Strengthen collaboration for vector research and training programmes in Africa: There is a growing need for research partners and programme implementers to work closely to develop innovative solutions to help solve the disease problems in Africa. As an internationally recognised research institution in Africa, *icipe* is well placed to be a WHO Collaborating Centre on IVM with the aim of backstopping and providing leadership in research and training for Africa. It is, therefore, our vision to strengthen these collaborative linkages and encourage disease-endemic countries to implement IVM as the rational approach to vector control.

3.2 Plant Health

(a) Overview of activities

The work of *icipe* in plant health contributes to improving sustainable food security and environmental health through developing IPM options for pre- and postharvest pests, and for parasitic weeds (such as striga), and biological control (BC) using arthropods. All technology development involves farmer participation to ensure their needs are met. The agenda of plant health research covers three domains: **Staple Food Crop Pests**, which is covered by the Habitat Management (HM) and Biological Control (BC) of Cereal Pests Programmes; **Horticultural Crop Pests**, which is dealt with by the Vegetable and Fruit Fly Research Programmes; and **Locust and Other Pests**, which deals with African and Madagascar migratory locusts, the armyworm and others.

Wherever possible, priority is given to solutions that minimise the impact on the environment and on human health, such as BC (classical and augmentative BC, microbial control), use of baiting stations and habitat management. *icipe* is the only international institution in Africa that has internationally accredited quarantine facilities. The facilities enable *icipe* to import and maintain exotic natural enemies once the Kenyan authorities have approved their importation. For more intractable problems, an in-depth understanding of the interactions between the soil, plant, pests and natural enemies in their cultivated and natural habitats is required. Such multi-trophic level studies often result in novel pest management technologies.

Further activities in *icipe* plant health analyse the economic impact of the developed technologies and assess factors associated with their success or failure. Also, the economic impact of good agricultural practices and international standards on export crop production is assessed as well as the dynamics in farmer training and technology transfer.

Staple food crop pests

Biological control of cereal pests

The programme's main focus was on research and development of IPM-programmes to combat lepidopteran cereal stemborers, and more recently on IPM of storage pests and moulds with emphasis on the invasive *Prostephanus truncatus*



(the larger grain borer [LGB]) and mycotoxin-producing fungi. In addition to field losses to large-grained cereal production in SSA, cob damage by stemborers renders the grain susceptible to *Aspergillus flavus* infection resulting in subsequent high levels of aflatoxin of field and stored maize. Thus, solving the stemborer problem would partly also solve the storage problems and help to reduce qualitative and quantitative losses in stored grain. Major emphasis is being given to BC, such as classical BC against the spotted stemborer *Chilo partellus*, and against the LGB, and in the case of indigenous stemborers, to the redistribution BC approach, which aims at expanding the geographical range of natural enemy species and strains. In addition, the programme researches IPM components that are based on HM-technologies that complement BC against both field and storage pests.

Before releases, in-depth studies on the biology and ecology of the borers and natural enemies, including the role of wild habitats as reservoirs/refugia for alternative hosts (other species of borers) for the natural enemy are undertaken, to understand the climate and ecological factors that determine the performance of the natural enemy. This approach of combining basic ecological research with collaborative implementation-oriented studies was key to the success of icipe's BC of stemborers projects. The programme built a network of well-trained BC scientists from 11 countries in East, southern and Central Africa. The programme put major emphasis on training of postgraduate students as well as extension agents, who then trained the farmers in IPM.

Habitat management

A novel HM technique developed by icipe (and collaborative partners) simultaneously combats stemborer and striga problems in cereal crops and is the so-called 'push-pull' strategy. This strategy involves repelling ovipositing stemborer moths away from the maize crop using *Desmodium* spp. as inter-crop (push), while trapping them on wild host plants such as Napier grass (*Pennisetum purpureum*) (pull). The striga control tactic, on the other hand, involves a desmodium intercrop that induces abortive germination of striga seeds, which fail to develop and attach onto the host cereal crop, thus suppressing and eliminating the weed. *Desmodium* also improves soil fertility through nitrogen fixation and moisture retention. The push-pull strategy provides synergy and complementarities to livestock integration and is an income-generation objective in smallholder mixed-farming systems practised in Africa and thus contributes to increasing food security and improving livelihoods of rural families on the continent. Institutional partnerships with the public and private sectors, and civil society have been created to expand the dissemination of the technology. The push-pull technology is also a part of the Farmer Field Schools curriculum in western Kenya.

Horticultural crop pests

The Centre has built a team of specialists in horticultural plant protection research that has conducted training courses at all levels and engaged in the development of IPM manuals and training materials. Expertise of this team covers entomology, plant and insect pathology, biological control, biopesticides, IPM research planning and implementation, design and performance of participatory training and learning, postgraduate training of local researchers, and economics. The team has a long-standing association with the export horticultural industry in Kenya and active cooperation with national research institutions in Kenya, Cameroon, Ethiopia, Malawi, Mozambique, South Africa, Tanzania, Uganda and Zimbabwe. Outside Africa, research collaboration is ongoing in Brazil, France, Germany, Peru, Taiwan, China, Syria and Romania. Currently, the team works on phytosanitary problems related to local market and export production of fruit and vegetables. One of the main efforts has been to develop IPM strategies that can be applied by smallholder producers to ensure their continued participation in export fruit and vegetable production.

Major research work is ongoing on biological control of the diamondback moth (DBM) in crucifers, integrated and biological control of the tomato red spider mite (RSM), integrated control of fruit flies and leaf miners, economic impact of biological control of DBM, the impact of European food safety standards on export vegetables as well as the impact of IPM training activities. The team also investigates basic research issues of strategic importance posed during the implementation of various research programmes (e.g. the expansion of host range by DBM to peas and its evolutionary significance). The

icipe horticulture programme has produced IPM manuals for cut flowers, crucifers, French beans, okra, tomatoes and mango and field-tested the quality management systems handbook for the implementation of EurepGAP¹ standard for vegetable production and adapted it to local conditions of Kenya.

Locust and other pests

Specifically, the focus of the desert locust programme is to carry out multi-site demonstration and validation trials on the effects of PAN on gregarious hopper-bands with or without fractional doses of bio- and chemical pesticides in collaboration with National Plant Protection programmes in desert locust-affected countries. The results from these studies will be used as a model for characterisation of PAN equivalents, if any, in the Madagascar migratory and red locusts.

(b) Goal and broader objectives

The aim is stabilising horticultural and staple food production by reducing quantitative and qualitative pre- and postharvest yield losses due to insect pests, mites, weeds and mycotoxin-producing fungi by contributing to the development of economically viable production systems that are less reliant on external inputs, in particular pesticides, and thus environmentally friendly and sustainable. The focus is to quantify economic crop losses due to pests, undertake research leading to sustainable and economically viable IPM solutions, and provide support for their implementation; and through collaborative activities, build national and regional capacity and capability to carry out these tasks independently.

(c) Strategic future plans (to 2012)

Horticultural production systems: *icipe* will continue to contribute to the development of horticultural production systems in compliance with international GAP standards, thereby contributing to sustainable, environmentally friendly production systems. Major thrusts will remain in the area of IPM and especially BC. The capability of plants to change their biosynthetic pathways to produce induced secondary compounds making them resistant to insects or attract natural enemies has now become the basis of 'pathway engineering' in entomological research. We shall also elucidate fruit fly responses to kairomones from host plants and industrial by-products to develop attractants, repellents, feeding stimulants and deterrents. Furthermore, we envisage characterising the demography of recent invasions by alien fruit flies to identify the source, pathways and origin of invasion and assess the genetic mechanisms involved in polyphagy, reproductive potential and other traits peculiar to invasions. Molecular markers will be developed for key parasitoids of the invasive species to measure if populations are genetically distinct and thus identifiable following release.

Also important for research and development in horticulture IPM, especially in view of the recent introductions of quarantine-relevant pests, is the scientific study of postharvest quarantine treatments. Attempts are also being made to better link work at the Centre to the private sector and to integrate research at *icipe*, the national programmes, local universities and other centres to identified demand of the export and local market production to ensure fast adoption of progress achieved in research programmes.

Climate change

Low-latitude regions in SSA are more vulnerable to the negative impact of climate change, especially global warming, than mid- and high latitude regions. Forecasts and simulation models predict that with global warming, crop pests will expand to higher altitudes and even outside of the tropics such as the Mediterranean, leading to an increase in the occurrence of alien pest invasions and expansion of the geographic range of indigenous pests. Climate change could affect the relationships between crop pests and their natural enemies, and lead to unexpected species interactions, and outbreaks of secondary pests. Predictive experimental models will be used to determine possible effects of climate change on key and occasional pests of selected target crops. Adaptive responses will be identified in

¹ EurepGAP standard was developed by the Euro-Retailer Produce Working Group (EUREP) and farmer representatives for the certification of Good Agricultural Practices (GAP) worldwide.

close collaboration with partner institutions to lessen or overcome the expected adverse effects on agriculture.

Functional agrobiodiversity: The efficacy of BC and HM technologies can be variable. Recent experience showed that this variability is partly due to the role wild habitats play in the invasion of crop fields by both pest and natural enemies: They can be reservoirs of both pests and beneficials—thereby increasing or decreasing pest attacks—or act as trap plants and, thus, as a reproductive sink. In future, increased emphasis will, therefore, be given to elucidating the role of functional agro biodiversity in plant protection with special reference to habitat fragmentation aggravated by the destruction of natural habitats and concomitant increase of agricultural areas. These studies will also include socio-economic valuation of ecosystem services provided by wild and cultivated habitats, such as BC and pollination. Based on this valuation trade-offs in the design of development interventions and the policy framework, e.g. trade-offs between conservation and development activities, will be assessed.

Habitat management and push-pull: As we continue with large-scale extension and diffusion of 'push-pull' technologies among smallholder farmers in Africa, it will be important to address future research questions addressing the challenges of the 21st century. In view of the expected climate change effects, more drought-tolerant companion plants will be screened and selected for long-term sustainability of the 'push-pull' system. To maintain optimal levels of soil nutrients and to reduce the need for mineral fertiliser application by resource-poor farmers, companion plants with both nitrogen and phosphorous fixation ability will be selected and incorporated in future push-pull systems. In view of the changing climate conditions and the need to optimise the ecosystem functions within the push-pull system, we will continue elucidating chemical ecology of existing and new companion plants and develop tools for quality control of the performance of the 'push' and 'pull' components. We will also exploit the use of semiochemical-based pest control strategies: (i) through working on induced release of plant volatiles after egg deposition by phytophagous insects which influence the behaviour of egg and larval parasitoids, and by improving the induced defence of maize in response to stemborer oviposition, and ii) studying the biochemical production and associated molecular biology of stress signals—nonatriene and (E)- α -ocimene—and working on location and cloning of the genes involved in production of these stress chemicals by undamaged molasses grass for possible transfer of these chemicals from molasses grass to maize. Given that now we understand the mechanisms by which *Desmodium* suppresses *Striga*, including the identification of secondary metabolites involved, transfer of the genes responsible for these traits into a food legume such as edible beans will be undertaken. Addressing this challenge will provide greater flexibility to farmers, particularly those without livestock, for controlling *Striga* and will contribute even more to stabilising and improving cereal production in the poorest farming regions. For removing the threat of Napier stunt disease to save the small-scale dairy industry in eastern Africa, molecular tools, such as PCR, will be used in identifying vectors of phytoplasma-causing Napier stunt disease, and for screening for sources of resistance.

With the possible threats of *Striga* and stemborers infestation spreading to new areas as a result of global warming, coupled with decreasing soil fertility and increasing human population pressure on land, there is need for increased adoption of pro-poor technologies such as push-pull, a technology that also supports crop–livestock integration allowing expanding of markets for livestock products. The challenge is on understanding the risks involved, their assessment, management and communication, and provision of scientific and technical information for policy makers. To address this, there is need to use improved evaluation methods and expanded impact studies, to gain a better understanding of how push-pull technology contributes to improved livelihoods and environmental sustainability. For developing optimal expansion strategies, the relationship between household socio-economic



status and land labour ratio in different regions, and the efficacy and cost-effectiveness of different diffusion mechanisms (mass media, field days and farmer field schools) needs to be clarified. Several new science-led maize production and protection technologies (IR maize, Bt maize and QP maize) have been developed by other research institutes, the effectiveness and sustainability of which need to be compared with the push-pull strategies over a longer time scale. Questions relating to potential integration of these technologies or their complementarities have been raised and need to be evaluated in continued collaboration with other centres (CIMMYT, TSBF-CIAT).

The role of agronomy and soil science in IPM: Most IPM techniques are based on agronomy and measures that improve soil fertility and thus plant health. A series of recent studies by *icipe* have shown that soil fertility not only affects plant growth and vigour but also affects pest infestation and damage as well as the performance of natural enemies. Furthermore, the ever-dwindling soil fertility in Africa is a major constraint of agricultural production. Thus, a closer linkage to institutes with the necessary expertise in agronomy and soil science will be sought.

Environmental risk assessment of genetically modified organisms (GMOs): The GM crops introduced into Africa have been developed and are promoted without technical backstopping by ecologists; thus, the risks to the environment and of resistance build-up are widely unknown and need to be thoroughly assessed before this technology is widely disseminated.

Food safety and mycotoxins: Mycotoxin-producing fungi such as *Aspergillus flavus* and *Fusarium verticillioides* produce toxic by-products that are carcinogenic and have immunotoxic properties and that cause unhealthy growth and immune suppression, and death in humans. Insects, such as lepidopteran stem- and cob-borers as well as storage beetles, were shown to be the vectors of these fungi. In addition, ear damage by insects renders the grain susceptible to fungal attack leading to high levels of mycotoxins. Thus, solving insect pest problems has been shown to significantly contribute to reductions in toxin levels in the field and store. A research project will be designed to identify the factors that increase or decrease the risk of aflatoxin contamination of maize grain, which will help to design IPM programmes to combat mycotoxin-producing fungi in the East and southern Africa region.

Expansion of IPM research to other locust species: Projects will be developed on the chemical communication systems of other locust species (e.g. Madagascar migratory and red locusts) in collaboration with national/regional locust control organisations. For both locust species, studies and results on the desert locust will be used as a model to understand the chemical ecology of these locust species and its role in gregarisation and outbreaks. Specifically, these studies will focus on the characterisation of the cohesion pheromones of different stages of the locusts and evaluate their potential in control with/without fractional doses of bio- and chemopesticides. A significant part of these projects is to build capacity in the locust-affected countries by training graduate students to oversee the R&D and management of these migrant pests in the long term.

Economic research related to plant and environmental health: International standards on good agricultural practices directly impact horticultural export production and may indirectly impact domestic production. This impact is being analysed; further, the potential of IPM and BC in attaining such standards will be assessed. Research will also be conducted on the economics of pest management through IPM strategies, BC as well as pesticides, and the interaction with human and environmental health. Economic valuation of ecosystem services and their interaction with human activity will be another area of research.

3.3 Environmental Health

(a) Overview of activities

The Centre's environmental health R&D emphasises the positive values of insects and currently comprises four major interlinked programmes: Commercial Insects; Applied Bioprospecting; Biodiversity and Biosystematics.

The Commercial Insects Programme (CIP) seeks to establish and consolidate apiculture and sericulture as significant contributors to rural livelihoods in Africa and the Near East. In addition to capacity

building (through the whole R&D spectrum from researcher to farmer) for traditional beekeeping and silkworm rearing, it researches the potential of wild stingless bees and wild silkworms (including forest and dryland species) for commercial applications. By demonstrating the commercial value of wild species, CIP provides support and motivation for biodiversity conservation. The programme's fundamental approach is based on close integration of investments into productive rural infrastructure, forest resources and human and institutional capital, and a way that reduces pressure on the protected biologically diverse ecosystem and its resources. It also emphasises on the empowerment of communities through ownership and operation of marketplaces in which value is added to bee and silk products through quality control, processing and packaging to national and international standards.



The Applied Bioprospecting Programme (ABP), together with the Behavioural and Chemical Ecology Department, undertakes research and capacity building in bioprospecting for useful products from biodiversity. It seeks to discover, develop and commercialise products from arthropods, plants and microorganisms for pest, vector and disease management, and industrial and other uses. The Programme has a high and a low technology approach. At the high-technology end, it has negotiated agreements between *icipe*, Kenya Wildlife Service (KWS) and other partners to discover, develop and commercialise agricultural pest control products, industrial enzymes and other products. Income that will be generated will be used to support management, protection and conservation of biodiversity, and research by *icipe* and its partners. At the low-technology end, it assists local communities living around important forests and other biodiversity-rich areas to undertake sustainable domestication and harvesting of aromatic and medicinal plants and to develop natural products for marketing.

The Biodiversity Conservation Programme has two major components: agrobiodiversity and biodiversity conservation. The agrobiodiversity studies focus on stemborers and risk assessment in relation to GM crops. The stemborer work examines the interactions between natural habitats and cereal crops through research on the diversity of stemborers and their natural enemies on wild and cultivated gramineous plants and related genera. Insect-resistant GM crops are an important component of the future of Africa's agricultural development. The risk assessment research focuses on cowpeas and the possible emergence of super weeds as a result of resistant transgenes spreading to wild relatives of cowpea.

The biodiversity studies concentrate on tropical forests since these host two-thirds of the world's insects. These studies have a particular focus on forests in global biodiversity hotspots, working with local partners and the Critical Ecosystem Partnership Fund (CEPF) of Conservation International (CI). *icipe* was the lead institution in compiling the Ecosystem Profile for the Eastern Arc Mountains and Coastal Forests (EACF) hotspot in Tanzania and Kenya. This profile resulted in the investment of \$7 million to support conservation actions in the hotspot by civil society. For the last four years *icipe* has also been the lead institution in guiding and administering this investment. More generally, *icipe*'s approach to biodiversity conservation is livelihood-based using the CIP and ABP to alleviate poverty and build support for forest conservation among forest-adjacent communities.

More recently the Biodiversity Conservation Programme has been researching the ecosystem services provided by forests (particularly carbon storage in the context of climate change) and by insects (particularly pollination, and particularly in proximity to forests). Carbon trading offers significant opportunities for financing forest conservation, especially as climate change is now a top issue on the global agenda. To access such funds, baseline data on current or recent carbon storage is essential. *icipe* has pioneered such studies in Kenya, determining the carbon levels in the vegetation and soils for four of Kenya's forests. To date these are the only such studies in the country.

The Biosystematics Support Unit has been mostly a service unit, facilitating identification for other projects within *icipe*, but also carries out targeted research to resolve taxonomic problems that arise in connection with projects (e.g. status of new and un-described invasive species, such as the exotic fruit fly *Bactrocera invadens*).

(b) Goal and broader objectives

The overall goal of *icipe*'s R&D activities in environmental health is conservation and sustainable utilisation of the agricultural production base and important natural ecosystems, by encouraging and utilising arthropod diversity, cataloguing and sharing biodiversity data, and discovering endemic wealth by bioprospecting for useful natural products.

Within this overall goal the following are broad objectives: (i) understand how arthropod agrobiodiversity and wild habitats support agricultural production and human health through ecosystem services (pollination, pest and vector control, maintenance of soil fertility); (ii) help to conserve forests in Africa's global biodiversity hotspots; (iii) use *icipe*'s technologies to alleviate poverty in forest-adjacent communities; (iv) establish modern apiculture and sericulture as significant contributors to rural livelihoods in Africa, (v) participate in global efforts to catalogue arthropod biodiversity; (vi) develop new natural products from plants and insects for the benefit of rural communities and others; and (vii) increase public awareness and appreciation of beneficial arthropods.

(c) Strategic future plans (to 2012)

Environmental challenges in the 21st century (see Section 1.2) set the stage for *icipe*'s environmental health R&D programme. The Division will continue to address the urgent issue of biodiversity losses with its focus on the conservation of the highly threatened hotspot forests, and will increasingly research the effects of such losses on ecosystem services, functional agrobiodiversity and human health. In the area of climate change, *icipe* will build on its pioneering carbon storage research in Kenyan forests by linking its livelihood initiatives, through appropriate tree planting (e.g. for nectar and pollen sources for bees and food plants for wild silkmoths), to carbon trading, both on-farm and in degraded forests. Increased capacity in the Biosystematics Support Unit (see below) should also allow for more involvement in the inventorying, cataloguing and monitoring of arthropod biodiversity, particularly within the new Eastern Afromontane hotspot. Altitudinal shifts in arthropod distributions are anticipated in response to climate change and can be monitored with relative ease, providing early and sensitive indicators of the effects of global warming and changes in rainfall distribution on arthropod populations. Where such shifts affect functional agrobiodiversity and disease vectors, there will be significant impacts on human well-being.

The current hotspot programme, focused on the EACF in Kenya and Tanzania, ends in 2008. It is expected that *icipe* will continue to engage with CEPF through a subsequent cycle of funding, but with less of an administrative role and a greater degree of research and development activities in collaboration

with *icipe*'s other programmes. For example, the success of *icipe*'s plant health biological control of DBM in the Taita Hills offers significant synergies with biodiversity conservation in the Eastern Afromontane hotspot. Thirty-two globally threatened species live in only 400 ha of forest in this critically important site within the Eastern Arc. Following the introduction of the parasitoid *Diadegma semiclausum* to control DBM, Taita farmers have abandoned intensive use of insecticides on their crucifer crops adjacent to these forests. The subsequent benefits for biodiversity conservation in the Taita Hills have not been quantified, but are certainly significant. *icipe*'s horticulture programmes in the Eastern Arc



present numerous environmental benefits that should be documented and quantified. The initial focus will be on functional agrobiodiversity, with subsequent research on possible impacts on biodiversity in the forests and water catchment areas.

icipe's CIP will remain as a key component in the environmental R&D activities portfolio. Insect-based enterprises are ideal for establishment in buffer zones adjacent to rich biodiversity habitats such as the hotspot forests. Activities such as sericulture, apiculture and butterfly farming are sustainable, eco-friendly, synergistic, and provide quick economic rewards. Where they utilise wild insects and plants from these habitats such activities are highly effective in building local support for conservation. Stingless bees and saturnid moths have great potential in this context. Honey from stingless bees is extensively used in traditional medicine in Africa. Thus, the medicinal uses of bee products (and the economic potential of wild silk) offer rich opportunities for future research. Commercial insects also offer good prospects for dryland revenue generation, particularly with bees and wild silkmooths that feed on dryland trees such as acacias.

To sustain an expanded CIP, greater effort will be needed to investigate the problems that will arise from scaling-up and intensifying insect enterprises across the continent. The clearest example concerns beekeeping and the dangers of emergent diseases and spread of invasive bee-pests such as the varroa mites. The establishment of a bee health laboratory is a clear priority (particularly in light of the recent and dramatic spread of the colony collapse disorder, currently threatening beekeeping and related pollination services in the US and Europe). Positive and negative impacts (e.g. on other pollinators and plants) from expanded beekeeping should also be investigated. Impacts on beekeeping are also anticipated in the context of climate change. These are likely to be both direct (through physiological/ecological effects on the insects themselves) and indirect (through an increase in invasive bee pests, and effects on the nectar, resin and pollen sources on which the bees depend).

The ABP will continue to undertake research and capacity building in bioprospecting for useful products from biodiversity. It will seek to expand its work on discovery, development and commercialisation of products for management of arthropod pests and disease vectors, and to source for new products from insects. The target pests will include crop and horticultural pests, mosquitoes and ticks. The Programme will work with its partners to transform some of the leads from its discovery process into commercial products. Collaboration with relevant partners will be strengthened and new partnerships established. It will also continue with its capacity building activities through training of more postgraduate students.

The ABP will develop new products from aromatic and medicinal plants that can be used to establish income-generating enterprises for local communities living around important forests and other biodiversity-rich areas. The capacity of the community members will be enhanced to undertake all the processes of the enterprises including sustainable domestication and harvesting of the plants, processing, product manufacturing and marketing.

Through *icipe's* Biosystematics Support Unit (BSU), efforts to secure support for taxonomy in the region will be intensified with a view to providing end-users with new IT and molecular tools (DNA bar-coding) for identification. It is also expected that this expert will strengthen the BSU ties to the global taxonomic community and international initiatives such as GBIF, through his background in the global taxonomy initiative of the Convention on Biological Diversity.

The major new areas for environmental health expansion will be in functional agrobiodiversity and the links between human health and environmental degradation. This will involve closer collaboration with the Human and Plant Health divisions and with external partners. Functional agrobiodiversity research will concentrate on the ecosystem services provided by arthropods, starting with pollination and natural/biological pest control, and emphasising the landscape context in which smallholder farms are embedded in a mosaic of natural and semi-natural habitats. Particular attention will be given to services provided by forest fragments. Links between human health and environmental degradation will be explored for mosquito-borne diseases, emphasising the negative roles of deforestation and industrial developments in the creation and expansion of man-made habitats for mosquito breeding.

3.4 Animal Health

(a) Overview of activities

Over two-thirds of the population in the developing world are small-scale farmers, many of who are dependent on livestock for their everyday survival. Improvement of livestock health and productivity, therefore, provides a significant opportunity to improve the livelihoods of these poor people and to help them escape the poverty cycle. It is also important to improve livestock productivity to meet the increased demand for livestock products and to enhance traction power of oxen for improved agricultural productivity.

Over the years, *icipe* has developed capacity along the full research continuum, from strategic basic research to adaptive research and finally to technology development and transfer through strategic partnerships. It has considerable expertise in quantitative vector ecology, behavioural and chemical ecology, and biocontrol and integration of this basic knowledge in developing technologies that farmers can use. Our research and experience in tsetse and ticks has generated technologies that enable farmers to undertake better ecological management of these major livestock disease vectors and help in intensifying and diversifying smallholder farming systems to generate more cash income and enhance food security. The emphasis has been on developing environmentally safe methods that can be applied together in tailor-made, site-specific packages. Components of such a package include *icipe*'s well-known NGU tsetse trap whose efficacy is enhanced by odour baits, biological control and the use of repellents. *icipe* is also one of the few organisations, despite its limited funding, that continues to conduct research into the control of ticks and tick-borne diseases, to develop integrated pest and vector management (IPVM) approaches which rely on biological control, use of botanicals and anti-tick pasture plants, repellents and behavioural modification of the cues ticks use to find hosts and preferred feeding and mating sites. Indigenous knowledge of communities in management of ticks is also being incorporated in developing appropriate strategies for ticks' control.

In the case of tsetse, the Division has considerable experience in community mobilisation, empowerment and organisation for undertaking tsetse and trypanosomosis control in different agroecosystems and animal husbandry practices. Capacity building at all levels of society is an integral part of all Division activities.

(b) Goal and broader objectives

icipe's animal health research aims to improve livestock health and productivity through the development of integrated strategies and tools for livestock vectors' control, thus leading to greater availability of meat and milk, hides and draught power. Research activities focus on developing simple technologies based on detailed understanding of vector behaviour, population ecology, and vector–host and vector–parasite interactions. The research focus has been on two important vectors affecting livestock productivity in



sub-Saharan Africa—tsetse flies, vectors of animal and human trypanosomosis, and ticks, which, among other diseases, transmit East Coast fever. Research on arthropod vectors with potential for transmitting zoonotic and transboundary animal diseases is planned.

(c) Strategic future plans (to 2012)

Research on vectors of trypanosomosis (both human and animal) and tick-borne diseases will continue. Greater use of genomics and bioinformatics, and behavioural and chemical ecology will be made for technology development and implementation. Research will be extended

to other arthropods of medical and zoonotic importance to develop technologies for the integrated management of these vectors and the diseases they cause. Climate change may increase the range and efficiency of vectors and *icipe* is prepared to deal with these consequences. More holistic projects will be developed to catalyse sustainable agriculture and rural development, improve livestock and human health and food security, and reduce poverty. Holistic, innovative, site-specific, packages for sustainable animal health management/production will be developed and tested at farmer levels in different production systems and agroecological zones for adoption and wider dissemination. Capacity building to create cadres of research/ vector control specialists and managers in livestock IPVM will continue to be given a high priority. Communities will also be capacitated to ensure sustainability of control efforts.

Specific future thrusts that are envisaged include:

Tsetse

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

The repellent technology developed by *icipe* will be further optimised and validated. The prototype dispenser developed will be technically refined to transform it to a robust device that can survive the mechanical stresses on cattle in the field. This will be addressed in partnership with the commercial sector since such technical refinement is beyond the scope of *icipe* laboratories. Validation trial will also be undertaken to determine under which herder conditions the technology would work best. The more potent waterbuck repellent blend that has been identified will be evaluated on cattle and an appropriate dispenser for the blend developed. The results will enable the transforming of cows into 'animals with waterbuck clothing'. Such protected animals would not only repel tsetse but also significantly reduce drug use and minimise the chances of developing drug resistance. Steps can then be taken to enhance the diffusion, commercialisation and uptake of the technology by the potential beneficiaries, who include agropastoralists and pastoralists.

Since the current repellents have been developed only for savanna tsetse, research needs to be extended to identify and develop potent repellents for the *palpalis* group of flies (riverine tsetse), which are major vectors of human sleeping sickness. Repellents would be useful in protecting humans from tsetse bites and thus significantly reduce cases of human trypanosomosis.

Development of artificial baits (both visual and olfactory) for riverine tsetse will continue, as no baits exist for these flies. These baits, once developed, will not only be effective monitoring devices but also important tools for suppression of fly populations.

GIS technology to guide deployment of baits, in identified hot spots of high fly densities and in mapping the benefits of tsetse and trypanosomosis control, will be an integral part of our future work.

Advances in genomics and bioinformatics, together with detailed knowledge of the behaviour of the flies will be used for optimising existing baits and for development of new innovative technologies. The role of tsetse pathogens in enhancing tsetse suppression and in sterile insect technique (SIT) will also be investigated.

Studies on the characterisation of tsetse–trypanosome interactions for a better understanding of the disease epidemiology and for the development of novel anti-parasite agents for blocking transmission of trypanosomes in the vector will continue.



As the main institute working on tsetse, *icipe* will undertake any backstopping research that will be required to implement area-wide control/eradication programmes. In addition, the institute is well positioned to undertake the much-needed detailed baseline entomological and parasitological surveys for intervention programmes, including monitoring the effects of climate change on the distribution and vectorial capacity of tsetse.

Biting flies

In addition to tsetse, blood-feeding biting flies (e.g. tabanids and stable flies) also mechanically transmit trypanosomiasis to cattle (termed nagana) and to camels (termed surra), considerably affecting their productivity. *icipe* will develop integrated technologies for control of biting flies based on exploitable weaknesses of the vectors along the lines of those developed for tsetse.

Ticks

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

Medical vectors of zoonotic importance

icipe will develop new tools and strategies for the integrated management of important arthropod vectors which not only impact transboundary trade but also those with great zoonotic potential. Basic knowledge on the biology, behaviour and ecology of vectors responsible for diseases such as bluetongue, lumpy skin disease and Rift Valley fever will be generated to guide development of appropriate control technologies. Development of diagnostic tools will also be undertaken. Production of predictive maps of disease burden for assisting in the identification of hot spots for guiding interventions will be undertaken.

Socio-economic and impact studies

icipe has long recognised that the quest for effective and sustainable vector control technologies will remain futile unless socio-economic and cultural (as well as environmental) considerations involving development and implementation of control technologies are taken into consideration. Socio-economic and impact studies will be undertaken in collaboration with other institutions and in particular with national systems who have considerable expertise in these areas.

Capacity building

To ensure sustainability of vector control, *icipe* will undertake capacity building at all levels including of service providers, practitioners, technicians, community health workers and managers of control operations.

Furthermore, to enable local affected communities to adopt, use and sustain intervention control strategies, *icipe* will help communities in the establishment of organisational, management and financial community structures as successfully done for tsetse control in Ethiopia through appropriate training, surveys and involvement of communities in the control effort.

3.5 Capacity Building and Institutional Development

(a) Overview of activities

Building human resource and institutional capacity has been an integral part of *icipe*'s mandate since its establishment, almost four decades ago. Within the area of insect science, it was clear that African countries lacked the necessary critical mass of scientists and institutions with capacity to undertake the relevant R&D work to provide the needed knowledge-based solutions to the development constraints resulting from arthropod pests and vectors. This implied the need for sustained human resource development in areas of scientific, technical, operational and research management, backed

up with overall institutional development for the productive use and expansion of that resource pool. Sustained capacity building effort has therefore been necessary to improve indigenous capability at all levels and institutional capacity to optimally use that capability.

From its genesis as a centre of excellence in insect science specialised in tropical problems and opportunities in Africa, *icipe* made significant investments in high-level manpower training at MSc, PhD and postdoctoral level. This was considered strategic for the growth of national R&D systems, which would eventually be expected to develop their own capacities to identify problems, and prioritise and undertake the necessary R&D work to address them.



It was also realised that a focus on capacity development at the higher echelons of the national systems needed to be backed up with training of extension workers and the beneficiary communities to facilitate the technology adoption process. *icipe* recognised that it would not have the capacity to train significant numbers of end-users and nor did it consider it desirable. Wider and rapid dissemination of the technologies would only be possible through training of extension staff in the national systems, who would in turn train the end users. To this end therefore, *icipe* has had a vibrant programme for on-site, interactive training of extensionists, technicians and end-users in specific research techniques or pest control technologies, as well as interactive technology development and adaptation with national staff, and farmers or herdsmen at country and sub-regional levels.

In general, there has been a major increase for demand of more of the capacity strengthening activities of *icipe*, especially the graduate programmes.

(b) Goal and broader objectives

The major objective of *icipe*'s capacity and institutional building programmes is to build human resource capacity in insect science and related areas of the biosciences that is well trained, highly motivated and able to respond to the arthropod-related development needs of its African constituency. Most importantly, *icipe*'s approach has been to acclimatise researchers such that they can function and perform within the African context, yet remain competitive within the global research and development marketplace. *icipe*'s capacity building effort has always been intricately in-built into its R&D programmes. These span the whole continuum, from basic strategic research to technology development and validation, and finally community-based adaptation. Hence, *icipe*'s training objectives at all levels are achieved as the Centre undertakes its core research work in fulfilment of its mandate.

icipe's current capacity building programme is complemented by collaborative arrangements with university and research institutions in developed countries. The programme is structured along the following major thrusts: (i) training at the postgraduate level for leadership in scientific research and policy formulation; (ii) technology dissemination to NRES through group training courses mainly targeted to practitioners in the national agricultural and health research and extension systems; (iii) professional development schemes, where postdoctoral fellows, research associates and visiting scientists come to *icipe* to develop and share expertise; (iv) interactive on-site training in participation with the beneficiary communities; (v) institutional development by nurturing and strengthening of African organisations and institutions; and (vi) fostering Africa-wide cooperation and networking to ensure a continental presence of *icipe*'s work.

(c) Strategic outlook (to 2012)

Education, especially at the postgraduate level, where research is an integral part of the training, will continue to be an important source of generating knowledge-based solutions to address the critical

constraints in national and regional development, more so in the areas of agricultural productivity, human health, and natural resource management. While this will be the case, there is a greater realisation that universities throughout Africa are facing severe financial problems coupled with a decline in the quality of the educational experience. For example, the Forum for Agricultural Research in Africa (FARA) has made an effort to identify what has gone wrong with university-offered agricultural education, through its sponsored network 'Building Africa's Scientific and Institutional Capacity' (BASIC) for Agriculture and Natural Resources. In its rationale, FARA states:

Education programmes in agriculture, forestry and environment are being delivered from dated, narrowly defined and specialised perspectives that will not produce graduates with the scope and analytical skills and technique needed to solve real development issues. Teaching is still following the assumed development processes of education–research–extension–adaptation–adoption. In other regions of the world, this sequential approach has given way to inclusive innovation systems approaches in which all actors contribute at all stages of technology and policy development thereby ensuring that supposedly 'proven' innovations will not be left on the shelf because of unforeseen problems further down the pipeline. The current content and delivery of agricultural courses are not inspiring students in agriculture because they are not getting the knowledge and skills they need to secure fulfilling careers. Often the employers have to retrain them before they can contribute effectively. Poor preparation of graduates has also weakened postgraduate programmes. Universities today pay too little attention to developing the soft sciences and skills in human resource management, project and institutional management, negotiating skills, conflict resolution, evaluation, monitoring, organising and sharing.

There also appears to be a strong gender bias in science training, with African female participation rates in the agricultural sciences in universities roughly half of those in other fields. These findings are very true across a wide spectrum of science training within universities. In its 2004 report, the Inter Academy Council (IAC) has noted that unless the current crisis in capacity building in areas of science is solved, Africa's next generation of students will be caught in a downward spiral, and the 'scientific divide' between the advanced North and the lagging South, especially in Africa, will be widened further.

Within the context of emerging issues, climate change and related issues of global importance will continue to be a prime concern for the African continent in the next two to three decades. The ability of African institutions and people to adapt to anticipated impacts of climate change is limited by widespread poverty, fragile ecosystems, weak institutions and other factors. It is quite clear that the poor in Africa will have the least adaptive capacity, and highest vulnerability to climate change. It is therefore imperative that *icipe* develops programmes aimed at developing the capacity of African countries to adapt to climate change.

Recent advances in methodologies and approaches in science also need to be factored into the curriculum used to train students. For example, developments in molecular biology have resulted in a number of significant cutting-edge research in functional genomics and biotechnology that have already been shown elsewhere to offer promising solutions to the challenges facing humankind. In order not to be left behind, Africa must position herself strategically to reap the full benefits that these new technological developments may offer. A number of training institutions in Africa, particularly at the university level, still do not have the capability of teaching and supervising research in these newer advances. *icipe* has a responsibility to help bridge the gaps within these institutions.

As a response to these challenges, and as a major research and training organisation working in Africa, *icipe* has the responsibility of ensuring that the incoming generations of African scientists and practitioners trained at the Centre have a strong and holistic science-based training within a socio-economic background that is relevant to the needs of the society they live and work in.



Graduate trainees need to be equipped with problem-solving and critical thinking skills, as well as possess good communication and interpersonal skills. Hence, *icipe*'s research training programmes need to be designed based on a holistic, interdisciplinary approach that is anchored firmly on a strong disciplinary pillar, emphasising the creation and application of knowledge, strengthening of skills and changing of mindsets so as to empower individual researchers and institutions to initiate problem-solving research that will impact on socio-economic development. To improve more on the quality, *icipe*'s graduates need to be readily conversant with modern concepts and principles of integrated pest and vector management (IPVM) and be able to conceive, develop and implement projects through multidisciplinary teamwork. The graduates need to be able to analyse insect-related aspects that impact on food and health security policies and effectively utilise contributions of other disciplines such as socio-sciences, economics and policy studies.

Within the international research context that *icipe* tends to operate in, the research agenda has shifted considerably over the recent decade from emphasis on increasing (usually crop) food productivity, to explicit attempts to reduce poverty and protect the environment. Increasingly, there are calls for capacity development to be concerned with strengthening the systems that interface between research and society and which can promote learning and innovation and related institutional factors (working practices, routines, norms and policies).

Recent discussions of innovation capacity have argued that capacity development in many countries involves two sorts of tasks. The first is to create networks of scientific actors around research themes such as biotechnology and networks of rural actors around development themes such as dryland agriculture. The second is to build links between these networks so that research can be used in rural innovation. It is probable that interventions that unite research-based and community-based capacity could cost relatively little, add value to existing investments, result in pro-poor innovation capacity, and achieve very high returns.

In its current vision and strategy, *icipe* interprets its mission to be more about contributing to poverty alleviation, income generation and improved human health. Two kinds of strategic investments are required for this vision to be realised. First, investing in institutional strengthening so that developing countries can build capacity to '*do it themselves*' and sustain the development process to uplift communities out of poverty and unlock the potential for development. Second, investment in the support of communities that are engaged not only as beneficiaries, but also as empowered drivers of change able to keep pace in the rapidly evolving world may perhaps yield the best returns.

Therefore, in developing a forward perspective for *icipe*'s capacity strengthening activities, there is need to focus on enhancing the dual complementarities between formal and informal training. As a future strategy, more emphasis will be made on need- and opportunity-based training, putting acquired skills and experience before formal training. In this regard, there is need to design and develop programmes that will strengthen weak linkages from both a value chain perspective as well as from an innovation systems approach. In general, it is strategically important to see more of *icipe*'s programmes and projects emphasising assistance to other training institutions through training of trainers (ToT) and working with qualified institutions and NGOs in undertaking the training function, especially at the beneficiary level.

Consequently, over the next five-year period, *icipe*'s capacity strengthening effort will be focused on the following four major thrusts:

- *Collaborative training through ARPPIS* will continue to be an important element of capacity strengthening at *icipe* with the Centre providing research facilities and supervision expertise for the student research project for the MSc and the PhD degree. The ARPPIS Network will be the major partnership framework for undertaking this training, recruiting 10–12 MSc and 7–10 PhD scholars annually. From an organisational development standpoint, and within the limitations of resource availability, the partners in the ARPPIS network (*icipe* and the universities) will work jointly to implement a number of measures towards cost-effectiveness and sustainability. These measures include:

- Enhancing the *level of participation* of universities in implementing the network programme;
 - Modernising and upgrading the *training curriculum* to meet the current needs of graduate training of an insect scientist;
 - Meet critical *institutional needs* of the partners, especially the universities. The use of ICT and distance learning approaches need to be examined as efficient methods of teaching where applicable; and
 - Exploit all *resource mobilisation* opportunities to fund the network programmes. This will mean developing proposals through a teamwork approach involving other universities.
- *Expanding training opportunities through DRIP:* The flexible arrangement provided through the Dissertation Research Internship Programme (DRIP), where bona fide university registered scholars undertaking training at MSc or PhD level from universities throughout the world access *icipe's* research facilities and benefit from world class supervision expertise continues to be a major attraction. Currently, requests are received from throughout Africa, as well as other parts of the world, for access to the programme. While it is important to maintain this flexibility, there is need to streamline and align more closely the expertise resident in *icipe's* programmes and projects to the needs of the sponsoring universities. There is also need to implement a realistic bench fee arrangement that will enable scholars to contribute to the costs of training (e.g. laboratory upkeep and costs of supervision, etc.).
 - *Expanding the scientific exchange visits programme* especially with universities from other regions of the world. This will be done through development of formal linkages with selected universities and negotiating on the logistics of mounting such a programme. The McGill University (Canada) has been discussing with *icipe* on hosting a postgraduate internship programme to enable their students to undertake 3- to 6-month internships in Africa plus a joint MSc course.
 - *Redesigning and expanding the group training courses:* Courses offered at *icipe* have tended to focus more on the adoption of a technology or scientific approach. While this is important, there is an increasing need to redefine the course curriculum in a more holistic way, especially in the context of development (improved livelihoods for the rural poor, poverty alleviation, food security etc.). In this category of training it is not sufficient to invest only on managing technical change. There is need to empower communities to continuously innovate within the dynamic environment they live in. There is further need to develop training courses targeting topical issues and concerns, such as climate change, biodiversity conservation, ecosystem services and management of invasive species. It is considered that *icipe* will capture an important niche if it can provide training in these areas.



4. Institutional performance

icipe's institutional performance will be judged from several perspectives:

- Impact in contributing to *icipe's* mission of improving human welfare at individual, household and community levels and restoring and conserving the environment;
- Capacity built at individual level and in institutional strengthening;
- Scientific outputs, as measured by the number and quality of research publications, reviews and intellectual property rights awards (patents);
- Technologies developed for the management of harmful and useful arthropods;
- Products, tools and strategies as elements of these technologies;
- Networks created through increased strategic collaboration with NRES, universities and IARCs;
- Increased funding from enhanced donor confidence in *icipe* management, research and development.

Monitoring of performance will be accomplished through the mechanisms of:

- Monitoring and assessment of client and partner satisfaction feedback and adoption of *icipe's* technologies;
- Periodic external reviews of scientific programmes and management;
- Internal peer reviews, by way of seminars and research conferences;
- Individual performance assessment, through regular annual performance reviews;
- The specific impact in terms of the economic return, area covered and people benefiting from *icipe's* and its partners' technologies.



5. Conclusion

From its African genesis some four decades ago, *icipe* continues to respond to the continent's needs and aspirations, through the pursuit of relevant, innovative and cutting-edge research and capacity building work. Be it in assisting policy makers, developing new technologies and human resources, securing production assets for the rural and urban poor, or market access for innovative products—all in close partnership with other African institutions—*icipe* has demonstrated that it is able to deliver good value for investments made.

That indeed is a firm institutional base to spring its strategic agenda for the next five years and beyond—alert and sensitive to the changing environment and emerging concerns, both from a regional as well as a global perspective.

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Acronyms and abbreviations

AAIS	African Association of Insect Scientists
ABP	Applied Bioprospecting Programme
ARPPIS	African Regional Postgraduate Programme in Insect Science
ASA	ARPPIS Scholars Association
BASIC	Building Africa's Scientific and Institutional Capacity
BC	Biological Control
Bt	<i>Bacillus thuringiensis</i>
CDC	Centers for Disease Control (light trap)
CFG	counterflow geometry (trap)
CI/CEPF	Critical Ecosystem Partnership Fund of Conservation International
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Centre)
CIP	Commercial Insects Programme
DBM	diamondback moth
DRIP	Dissertation Research Internship Programme
EACF	Eastern Arc Mountains and Coastal Forests
EPF	entomopathogenic fungi
ESA	East and Southern Africa (region)
FAO	Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
GBIF	Global Biodiversity Information Facility
GIS	geographical information system
GMO	genetically modified organism
HAT	human African trypanosomosis
HIV/AIDS	human immunodeficiency virus/acquired immunity syndrome
HM	Habitat Management
IAC	Inter Academy Council
IARC	international agricultural research centre
ICT	information and communications technology
IGR	insect growth regulator
IPM	integrated pest management
IPR	International Property Rights
IPVM	integrated pest and vector management
IR	Imidazolinone-resistant
IRD	Institut de Recherche pour le Developpement
IT	information technology
IVM	integrated vector management
KWS	Kenya Wildlife Service
LDC	least developed country
LGB	larger grain borer
MDG	millennium development goal
MTP	medium-term plan
NARES	national agricultural research and extension systems
NGO	nongovernmental organisation
NRES	national research and extension systems
PAN	phenylacetone nitrile
PDF	Postdoctoral Research Fellow
QP	quality protein (maize)
R&D	research and development
RBM	Roll Back Malaria (Partnership)
RSM	red spider mite
RVF	Rift Valley fever
SIT	sterile insect technique



SRO	sub-regional organisation
SSA	sub-Saharan Africa
ToT	training of trainers
TRIPS	Trade-Related Aspects of Intellectual Property Rights
TSBF-CIAT	Tropical Soil Biology and Fertility Institute of Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WHO/AFRO	World Health Organization Regional Office for Africa
WTO	World Trade Organisation
WWF	World Wide Fund for Nature

For more information, see the link to the *icipe* webpage (<http://www.icipe.org>)



icipe is a unique and advanced research and training organisation working to improve the lives and livelihoods of people in Africa. Because insects and other arthropods have a major impact in almost every area of their physical well-being and prosperity, **icipe** is making its contribution by continuing to improve the plant, animal, human and environmental health of, primarily, smallholder farmers and disadvantaged urban dwellers in Africa.



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