SO4. Health and sustainable food production has been improved through the prevention and mitigation of risks that originate at the interface between humans, animals and their various environments

Photo 4. *Searching for aquatic snails that transmit bilharzia or fasciolosis (ATRAP)* – R.Schols © RMCA

1. Contributions to strategic objective 4

A. ATRAP

Action Towards Reducing Aquatic snail-borne Parasitic diseases

Expected outcome 4A: *Aquatic snail-borne parasitic diseases are better prevented through a monitoring approach that actively involves the communities at risk (in DRC and Uganda).*

Countries where the activities take place: Uganda, DRC

Summary

Snail-borne diseases, including schistosomiasis, form a major public and veterinary health burden, especially in sub-Saharan Africa. Despite regular mass drug administration (MDA) schistosomiasis continues to (re-)emerge. Research demonstrated that a limited knowledge, risky water practices, and negative attitudes and beliefs about schistosomiasis increase the risk of infection. Therefore, snail control and health education are essential components of elimination programs. ATRAP aims to develop a novel snail monitoring approach that can be executed by non-specialists: citizens will be actively involved in snail monitoring, but will also act as communicator to the wider community. Apart from effective awareness and education, this '*citizen science*' approach will allow to significantly increase the scale and resolution of snail monitoring, generating the much-anticipated ecological data to create reliable risk maps and help policy makers in targeted snail control.

Keywords: Citizen science, vector-borne diseases, epidemiology, risk assessment, spatial modelling, health communication

Partnerships:

- Mbarara University of Science and Technology (MUST), **Uganda**
  Faculty of Science, Department of Biology
  Faculty of Interdisciplinary Studies, Department of Environment and Livelihood Support Systems
- University of Kinshasa (UNIKIN), **DRC**
  Institut National de Recherche Biomédicale (INRB), Department of Epidemiology

RMCA promoters: Tine HUYSE (Biology), Olivier DEWITTE (Earth Sciences), François KERVYN (Earth Sciences)

Involvement of other Belgian institutes:

- KU Leuven, Faculty of Sciences, Division of Geography
- KU Leuven, Department of Anthroplogy
- Institute of Tropical Medicine (ITM), Department of Biomedical Sciences, Medical Helminthology Unit
- University of Antwerp (UA), Faculty of Social Sciences, Research Groups MIOS and Cello

a) *General context*

Development problem that ATRAP wants to tackle and its sectoral context

Main context: In 2014, the World Health Organization (WHO) highlighted **vector-borne diseases** as a global public health priority. They affect more than 1 billion people, mainly in developing countries. Among these diseases, **schistosomiasis** ranks second only to malaria in terms of prevalence and morbidity. This poverty-related disease affects more than 200 million people worldwide, with the vast majority living in Africa (Gryseels et al., 2006). It is caused by parasitic worms that are transmitted by freshwater snails. Chronic infection in humans may lead to severe liver, intestinal and bladder complications and infertility, causing debilitating illness, sometimes leading to death. It is also of great **veterinary** importance, together with fascioliasis, another important snail-borne disease, leading to production losses and mortality in livestock.

Hence both diseases necessitate a **One Health** approach.
The last decades, the control of schistosomiasis has focused on mass drug administration (MDA) among school-aged children. However, schistosomiasis continues to (re-)emerge and scientists agree that MDA alone does not suffice (Sokolow et al, 2016; Tchuem Tchuente et al, 2017). This is linked to several factors. Parasite populations that reside in snail populations and animal (eg cattle, sheep) reservoirs are not affected by MDA and will re-enter the system after treatment. Moreover, a recent study by the Performance Monitoring and Accountability 2020 research program in Uganda (PMA2020 Uganda) showed that schistosomiasis prevalence returned to pre-treatment level one year after treatment, indicating that re-infection is high. Research demonstrated that a limited knowledge, risky water practices, poor sanitation and negative attitudes and beliefs about schistosomiasis increase the risk of infection (Sacolo et al., 2018). Therefore, **snail control, identification of animal reservoirs and health education** are essential components of elimination programs.

Problems related to research:

Since snail distribution determines where snail-borne diseases occur, updated information on snail distribution and their role in parasite transmission is highly needed. Acquiring these insights is however hampered by a strong lack in trained malacologists in Africa and elsewhere (Ademo et al., 2012, Shiff, 2017) and a lack of associated ecological and parasitological data.
Knowledge on snail distribution would assist national control programs for targeted snail control. This will reduce both human and animal parasite populations residing in snails at once. Regular monitoring will be essential in endemic provinces targeted for, or approaching elimination, to prevent re-emergence of the disease as well as in non-endemic provinces to prevent new outbreaks (Kincaid-Smith et al., 2017). Big data tools such as GIS (Geographical Information System) - based spatial analysis may be suitable and quick response methods to detect snail habitats. Transmission is furthermore linked to behavioral and socio-economic factors (see Fig. 4), which should thus be an integral part of the risk models.

Problems related to policy and control:

With respect to Uganda and Congo, knowledge gaps exist on active and putative transmission sites at policy level, especially for remote areas. A recent review by Mandinga et al. (2015) showed a significant lack of recent figures on schistosomiasis prevalence in Congo, while malacological data is virtually absent. Nevertheless, ongoing studies by ITM and INRB in Congo reveal very high prevalences and infection intensities. The national program has expressed their need for trained experts in malacology in order to set up adequate monitoring and vector control programs. A unit of vector control has been created within the national program for the control of NTDs amenable to preventive chemotherapy. However, this unit is not actually functional due to lack of human and material resources. This lack of local expertise in the field of malacology deprives the country of a clear plan of vector control, which could strengthen the achievements of mass treatment campaigns. For Uganda, a recent map of schistosomiasis prevalence was produced by PMA2020, showing that mean prevalence is high (30%). However, many areas were not included in the survey, as is the case for southwestern Uganda. Recent snail surveys by Justus Liebig University Giessen (JLU) and MUST however demonstrated the presence of suitable snail hosts in and around Mbarara. If the number of trained experts in malacology and parasitology increases, a more adequate monitoring system could be put in place in place in both countries. Lastly, policy and control 'suffer from a lack of temporally dynamic and spatially explicit risk models and maps that are needed for targeted snail control.

Problems related to community awareness:

As put by Sacolo et al. (2018): "health education should be the heartbeat of all health promoting interventions in order to yield sustainable positive changes". A meta-analysis conducted by Sacolo and colleagues highlighted the great need for changes in knowledge, attitudes and practices (KAP) in relation to schistosomiasis prevention and control in sub-Saharan Africa. In MDA programs where health education was included, an increase in KAP was found. PMA2020 Uganda formulated the following challenges for the control of schistosomiasis: poor medicine

uptake, inadequate health education for behavioral change to open defecation and medicine uptake, poor sanitation, and absence of snail control measures. For DR Congo, PMA2020 data on schistosomiasis are not (yet) available, demonstrating the need for anthropological studies on the attitudes and beliefs regarding schistosomiasis. Several initiatives have been taken by the Minister of Heath for the promotion of health education, hygiene and sanitation, such as UNICEF's "Clean Village" program (https://www.unicef.org/drcongo/french/wes_846.html). However, recent studies carried out by ITM and INRB in the west of the country, reported a small proportion of toilet ownership and use in this region (Madinga et al., 2017a,b). This suggests the existence of factors that negatively influence the acquisition and use of knowledge from these programmes in these endemic areas. Hence, there is an obvious need for anthropological studies on the knowledge, attitudes and beliefs regarding schistosomiasis. In both countries a better understanding of risks together with improved health education and more active inclusion of local communities are essential to increase knowledge and induce behavioral change.

Gryseels, B, et al. The Lancet, 368, 1106–1118 (2006); Kincaid-Smith, J. et al.Trends Parasitol. 1–10 (2017); Madinga J. et al. Parasit Vectors. 19;8:601 (2015); Madinga J. et al. Acta Trop. 171:186-193 (2017a); Madinga J.et al. Acta Trop. 165:100-109 (2017b); Sacolo H, et al BMC Inf. Dis. 18:46 (2018); Shiff, C 2017. PLoS Negl Trop Dis 11:e0005812. (2017); Sokolow et al. PLoS Negl Trop Dis 10: e0004794. (2016); Tchuem Tchuente et al. Infect Dis Poverty 6 (2017); Wang, L. De et al. Trop. Med. Int. Heal. 14, 1475–1483 (2009); Zhou, X. et al. Acta Trop. 82, 199–205 (2002).

Capacity constraints and needs of the partner institutions

Currently, the expertise in vector-borne diseases in Uganda is concentrated in the Vector Control Division at the Ministry of Health in Kampala. For Congo, there is a unit of vector control in each of the national programmes for the control of vector-borne diseases. These units work in collaboration with entomological services of INRB and one of the departments of tropical medicine at UNIKIN. Molecular facilities and expertise to identify snail and parasite species are currently lacking in Uganda. In Congo, there are molecular facilities at INRB, but not being applied for snail identification. By providing molecular training, equipping the laboratory, and developing molecular diagnostic tools, both teams will be able to perform long-term monitoring studies in hitherto unstudied regions.

In addition, there is a lack of PhD graduates in the field of malacology and parasitology at MUST in Uganda. However, the Department of Biology has recognised this capacity gap and has recently introduced a programme in Microbiology and Parasitology to strengthen this field. Congo has 'delivered' more PhD graduates in the field of parasitology (eg through INRB, UNIKIN), but hardly in medical malacology. ATRAP will therefore increase the number of trained staff and PhD and MSc graduates, thereby boosting the involved departments. ATRAP will enable MUST and UNIKIN to strengthen participatory and interdisciplinary outreach research platforms involving scientists, local communities and multi-actors ('Citizens' Science' approach) in controlling vector-borne diseases. For this, MUST has a rich experience of community engagement in research and student training. In addition, by training PhD and MSc students, ATRAP will provide the entomology unit of UNIKIN with expertise needed to assist the national program against NTDs to design and achieve comprehensive vector activities. Furthermore, ATRAP will help address the limited human and financial capacities in field research, hence providing adequate data and authority to inform policy on vector and disease control from a community approach.

As a result of the absence of strong malacological tradition in both countries, evidence-based policy implementation to reduce related health risks is extremely challenging. There is currently no official data available on the distribution and prevalence of schistosomiasis and fasciolosis in and around Mbarara and adjacent districts. Also in Congo, recent data on schistosomiasis and fasciolosis is lacking, and malacological data is virtually absent. With a strong focus on developing

research capacity in both countries, ATRAP will generate the necessary data for the Ministry of Health in both Uganda and Congo to fill these knowledge gaps and implement the necessary control strategies where needed. Moreover, the planned KAP studies are needed to optimize educational activities to be implemented alongside national control programs.

b) ***Background***

Partnership/ownership

Uganda: The ATRAP idea emerged through a combination of factors, including existing collaborations with Uganda and Congo, and recent discussions between the Biology and Earth Science department of the RMCA. There is currently a collaboration between RMCA, Giessen University, Lille University and MUST in the frame of a Belgian Belspo Pioneer project. This project was based on previous collaboration between JLU Giessen and MUST that highlighted putative transmission sites based on prospective malacological studies. The first exchanges were made by email followed by a joint meeting at Mbarara University beginning of August 2018 with the Ugandan partners and the RMCA coordinator to further discuss the content of ATRAP. During this trip more field sites were visited and malacological and parasitological surveys were carried out. The citizen science component of ATRAP builds upon experience from a VLIR-SI initiative (VUB) carried out in the Rwenzori Mountains (Uganda), whereby natural hazards are monitored by a team of local observers. The team of Olivier Dewitte and François Kervyn from the department of Earth Sciences (RMCA) were partners in the program and Lies Jacobs ((Division of Geography; KU Leuven, former RMCA) developed the citizen science component. Through informal contacts between the Department of Biology, and Earth Sciences (RMCA) and the Division of Geography (KU Leuven) the idea of using citizen scientists in snail-borne diseases emerged.
The programme officer of Bilharzia and Worm control at the Vector Control Division of the Ugandan Ministry of Health was contacted to enquire about the prevalence of schistosomiasis in Uganda, and the current status of schistosomiasis control in Uganda. These data were taken into account when choosing the sampling sites within Uganda.
Congo: Long-term collaborations exist between RMCA and ITM, and ITM and INRB (see below), on schistosomiasis as well as other tropical diseases. In the past years, Polman and Madinga, were involved in a comprehensive epidemiological survey on schistosomiasis in Kimpese. This included a malacological pilot study into the gastropod snail species at the transmission sites as well. Unfortunately, insufficient budget was available to conduct proper spatio-temporal analyses to link them with the generated epidemiological data. This will be possible in ATRAP. Also, Polman was the promotor of the PhD thesis of Dr. Madinga on the 'Epidemiology of polyparasitism with schistosomes, *Taenia solium* and soil-transmitted helminths in co-endemic settings of the Democratic Republic of Congo', while Huyse was member of the PhD thesis committee (2017). In last couple of years, Prof Lapika (Unikin) and Prof Pype (KUL) have started collaborative projects in the field of anthropology. In this context, they prepared a project on the use of mobile apps in Congo for funding from VLIR.

Previous experiences between the partners

ATRAP strongly builds on previous collaborations and projects, but due to the inclusion of new research disciplines it is an entirely new project.

- 2017-2020: Belspo Pioneer project: *TRojan snAILS: the role of gastropod snails in disease transmission revealed by state-of-the-art molecular techniques*'. (PI: Huyse, co-PI: Albrecht & Van Bocxlaer).
- 2010-2013: FWO research project: *Schistosomiasis: the role of parasite genetic diversity in human infection and pathology* (PI F. Volckaert, co-PI: Huyse, Polman).

- 2014-2018s: Poly-P (ITM-INRB): *an eco-epidemiological study on helminth co-infections and related morbidity in a rural area* of Democratic Republic of Congo: towards control of polyparasitism (PI: Polman & Lutumba)
- 2014-2015: Huyse and Poels published an opinion paper on Citizen Science in Flanders, Belgium in order to inform both the academic and wider community on the possibilities of and trends in Citizen Science. Best practices and policy recommendations were formulated.
- 2009 – to date: Collaboration between Biology department at MUST and JLU Giessen exists through several B.Sc. and M.Sc. research projects in the fields of medical malacology (PI: Albrecht, co-PI Tolo & Kagoro). One of the PhD candidates (Julius Tumusiime) from MUST has undergone specialized training in malacological studies at Giessen and continues to assist in field data collection for various projects.
- 2017-2018: VLIRUOS: VLIR-SI project (L. Jacobs). Enhancing community-based natural resources and hazard management in Rwenzori Mountains, Ongoing project (VUB): Within this VLIR-SI project a network of volunteers was established that report on disasters in their direct environment in the Rwenzori Mountains (Uganda). The network is currently collecting data on a daily basis in a very remote context and serves as a pilot for the construction of the citizen science component.
- 2017-2018: Prof Lapika and Prof Pype applied for VLIR funding (TEAM project) on 'electronic modernity' in Kinshasa in 2017 (not granted) and resubmitted this in 2018 (outcome end of September).

c) ***Theory of Change***

ATRAP's overall aim is to aid in the prevention of snail-borne diseases in Uganda and DRC, thereby lowering the socio-economic burden created by these diseases. The problem analysis allows to identify the different aspects where change needs to occur in order to strengthen the capacity to prevent infections by snail-borne diseases. Based on this problem analysis three main domains of change are formulated:

1. *Challenges related to research*: the local universities become more research active in the domain of snail-borne diseases, with regard to snail monitoring, risk modelling and active community involvement.
2. *Challenges related to policy and control*: policy makers are better informed through updated and accurate snail distribution data and high risk zones for transmission of snail-borne diseases
3. *Challenges related to community awareness*: the community is better informed through education and active participation in the prevention of snail-borne diseases.

In order to tackle the first problem, **interdisciplinary research groups** will be created. The obtained expertise in malacology in local universities will allow to monitor the distribution of snail that act as a vector for schistosomiasis and fasciolosis. Parasitological training will allow to identify infection of these snails with schistosome and other helminth parasites both through classical and new molecular methods. At the same time, the molecular diagnostic tools applied to animal stool samples will uncover animal reservoir species. Subsequently, snail vector distribution models and risk assessments will be created. However, in order to support the snail monitoring and at the same time tackle part of the third problem (community awareness), ATRAP will develop and enrol a novel vector monitoring approach that can be executed by non-specialists. A well selected group of citizens will be actively involved in snail monitoring, but will also act as communicators to the wider community, resulting in a multiplication effect. Apart from effective awareness and education, this '***citizen science***' approach will allow to significantly increase the scale and resolution of snail monitoring, generating the much-anticipated ecological data that serves as input to the risk assessment models in order to create reliable temporally dynamic and

spatially explicit risk maps (problem 2). These maps can be consulted by local health centres and ministries to implement preventive measurements including targeted snail control.

In order to increase the feasibility, sustainability and impact of this project, evidence-based policy development and implementation based on the results of the scientific activities described above, needs to be facilitated. To achieve this, a **multi-partnership** will be built by including key stakeholders, ranging from local communities and health centres, to NGO's, universities and ministries. Finally, community awareness and the resulting human behaviour are detrimental for the risk infection cycle. Given the complexity of vector-borne diseases cycles, which depend on biotic, abiotic and socio-cultural factors (Fig. 4), an integrative approach is vital for effective and successful risk reduction. Therefore, the interdisciplinary research team consisting of ecologists, epidemiologists, geographers, anthropologists and communication experts will stay in close collaboration with local policy makers, civic partners, citizen scientists and NGOs through frequent feedback moments. Outreach and awareness raising will also be a direct objective that will be achieved through the citizen scientists who will be important not only in data collection but also in information dissemination. Informative videos, posters and leaflets will also be distributed. This **community-centred eco-bio-social approach** seems to be best suited to break the downward spiral of neglected tropical diseases.

Sphere of control: Scientific expertise in local universities will be increased through development of new monitoring protocols for snail and parasite surveys. Scientific knowledge is increased through 1) long-term spatio-temporal data on snail and parasite distribution by students and citizen scientists; 2) building explicit risk models and maps, 3) performing KAP (*Knowledge, Attitudes, Practices*) studies in local communities to identify knowledge gaps that can be translated to adapted education strategies regarding snail-borne diseases and best practices to avoid schistosomiases infections.

Sphere of influence: Health officials and local governments know how to use and interpret spatial decision support systems for targeted snail control through regular exchanges during organized workshops and the production of policy briefs. Local communities are aware of the risks, consequences and prevention of snail-borne diseases.

Sphere of interest: The combination of MDA and targeted snail control will reduce the prevalence of parasite populations in the communities, snail and animal populations. The addition of health education tailored to the respective communities will induce behavioural change that will reduce exposure to schistosomiasis and other snail-borne diseases. Both results should ultimately lower the prevalence of snail-borne diseases in these areas.

d) Expected results

R1: Strengthening scientific research capacity

The local university's research capacity and expertise in snail-borne diseases increased, both in Uganda and Bas-Congo. Not only the number of trained staff and students will be increased, but new tools will also be developed and laboratories better equipped to conduct regular monitoring on the distribution of snail vectors and the diseases they transmit. Regular visits of Africa-based PhD students to the North and Europe-based PhD students to the South will broaden their scientific and personal horizon.

R2: Strengthening physical and virtual diffusion of scientific research results to the larger scientific community

The scientific community is informed on the methodologies behind modelling the distribution and drivers of snail-borne diseases in data-poor contexts such as south-western Uganda and Bas-Congo. Besides publications, presentations at international conferences and interactions at scientific network events, a website developed for local health staff and general public (see R4) will also contain detailed information and references on the methodological tools and models used within this project.

R3: Awareness raising towards the general public

The knowledge and awareness of local communities on snail-borne diseases is improved. The general public will be involved at different levels, both as public (information sessions, workshops) and as active participants (data collection and dissemination of results; the so-called 'citizen scientists').

R4: Support to good governance, based on the scientific results
The local governments obtain a better knowledge on the existence of putative and on-going transmission sites of snail-borne diseases that affect humans, livestock and wildlife, allowing for targeted (snail) control in combating neglected tropical diseases.

R5: Development of synergies and complementary activities among partners through multi-partner governance and coordination
A strong multi-partner network on snail-borne diseases is created, linking national and international research institutes, NGO's, policy makers and other stakeholders through regular meetings, workshops and email exchanges.

e) ***Methodology***

Each of the results above acts as a cornerstone for the development of the methodologies and actions below. The results are first concretized to fit the core objective of ATRAP, i.e. to aid in the prevention of infections by snail-borne diseases in southwestern Uganda and Bas-Congo. This entails understanding all aspects of risk factors as depicted in Fig. 4, and thus includes understanding the biotic and abiotic conditions and socio-cultural factors (orange influencing the infection cycle (white). To do so, a variety of different actors will contribute to various aspects of data collection (green). Finally, the final objective is only achieved if community outreach, capacity building and science communication (pink) are well embedded within and throughout ATRAP.

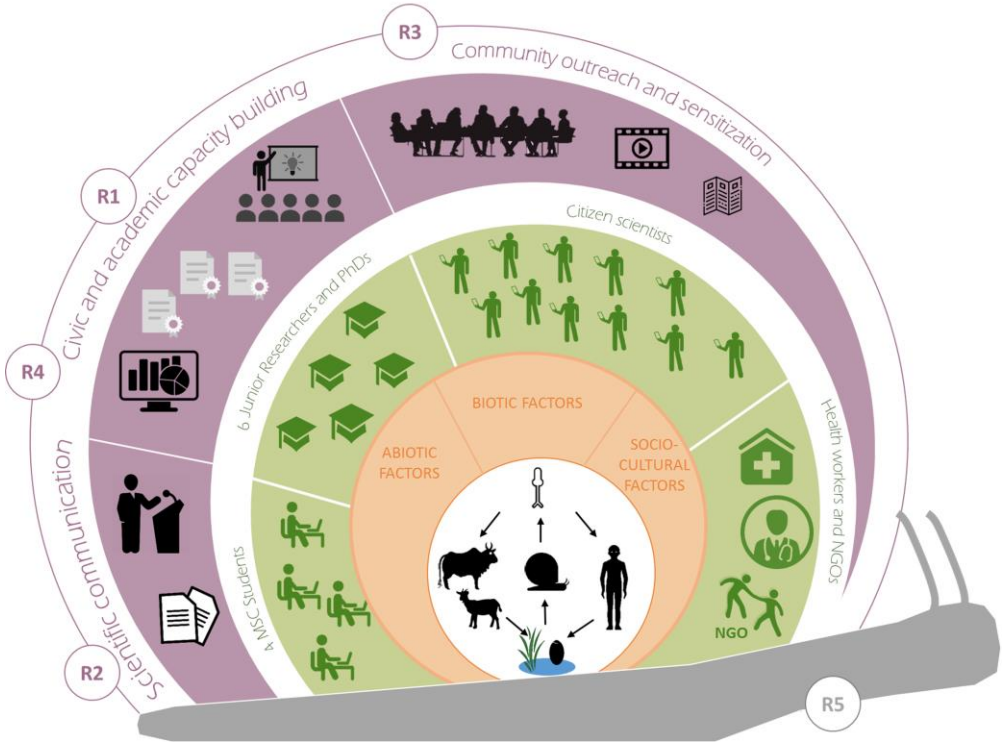

Fig. 4. *ATRAP methodology*

R1: Capacities and expertise of MUST and UNIKIN regarding snail-borne diseases increased.
Activity 1.1 Training and co-supervising of students in scientific research, writing and fieldwork. An overview is provided in Table 1:

Students	Scientific field	University**	Supervision*
PhD 1	Social sciences	MUST	MUST/UA/RMCA
MSc 1	Social sciences	MUST	MUST/UA/RMCA
PhD 2	Biological sciences	MUST	MUST/RMCA/JLU
MSc 2	Biological sciences	MUST	MUST/RMCA/JLU
PhD 3	Social sciences	UNIKIN	UNIKIN/KUL/RMCA
MSc 3	Social sciences	UNIKIN	UNIKIN/KUL/RMCA
PhD 4	Biological sciences	UNIKIN	UNIKIN/RMCA/ITM/UL
MSc 4	Biological sciences	UNIKIN	UNIKIN/RMCA/INRB/ITM
PhD 5	Geography	KUL	KUL/RMCA/MUST/ITM
MSc 5 +* **	Exact and social sciences	KUL/UA	KUL/UA/RMCA/MUST/UNIKIN/ITM/INRB

Overview of junior researchers that are trained within ATRAP activities.

**MUST: Mbarara University of Science and Technology; UA: University of Antwerp; RMCA: Royal Museum for Central Africa; JLU: Justus Liebig University; KUL: University of Leuven; ITM: Institute of Tropical Medicine; UL: University of Lille; INRB: Institut National de Recherche Biomédicale.*
*** PhD's are now considered as local PhD's (with 3 months research stay in Belgium each year) but extra funding will be sought after through existing channels of the involved universities and research institutions to create official sandwich PhDs with double degrees.*
**** Belgian MSc students (not paid) will be involved in ATRAP through the master program of the northern universities, these depend on available candidates and can therefore not be predicted.*

Activity 1.2. Fieldwork: Protocols for site and snail collection, water quality analysis, questionnaires etc will be fine-tuned during the kick-off workshop (below). The Ntoroko Districts and the Lake George-Kazinga Channel-Bunyaruguru craters-Kyambura gorge system have been selected for Uganda based on the high prevalence of schistosomiasis; for the DRC this will be the Kimpese Health District because recent epidemiological data on schistosomiasis prevalence is available through studies by involved partners (see above). Before the start of the malacological/ecological fieldwork, the social science PhD students will start with the collection of *socio-cultural data* (even though this work package and its actions falls under capacity strengthening of local universities, these will be discussed in R3 as it is to a large extent centred around community awareness). The selected study sites will first be studied in detail by the PhD students to create a baseline, before the involvement of citizen scientists (Y1; PhD 2 and 4, with help from MSc 2 and 4 later in the year).
In the next step, snail sampling will occur at all major water contact points in each village, together with the measurement of *biotic* and *abiotic factors*. These include geo-referenced environmental data such as water pH, temperature, DO, EC and macrophytes, but also the collection of fresh animal stool samples for later PCR (Polymerase chain reaction) analyses. This will be repeated monthly over three years. At the same time, after the creation of the baseline, citizens will be selected in every village to create the 'citizen scientists' network (see 1.5). These citizens will be trained in safe snail collection procedures and basic abiotic measurements in order to conduct weekly monitoring of the snail community at the 5 most important water contact points (defined in the baseline study) per village. The snail collection will be photographed with a smartphone and uploaded on a central server (e.g. www.kobotoolbox.org) that can be accessed by the local PhD and MSc student to validate all records, identify all snail species and process the environmental data. A network of automatic rain gauges will be installed in the study regions (Y2,3,4; PhD 2 and 4 and MSc 2 and 4).

Activity 1.3. Molecular analysis: All snail and animal stool samples from the baseline study will be identified based on morphological and molecular analysis. All animal stool samples will be

analysed by an optimized multiplex PCR assay during research stay in Belgium (end of Y1 + Y2; PhD 2 and PhD 4, MSc1 and MSc2).

Activity 1.4. Spatio-temporal modelling: Spatially explicit models will be obtained through statistical multivariate analysis using the data collected through fieldwork and by citizen scientists coupled with remote sensing data to understand the local and regional drivers for snail presence. Hydrological GIS procedures and snail population dynamics models will be used to understand snail dispersal routes and their seasonal dependency. Combined with spatially explicit population density data, transmission foci relevant for targeted snail control will be determined. (Y1/2: assembling and collecting data, Y2/3/4: spatio-temporal modelling with increasing complexity, PhD 5).

Activity 1.5. Create citizen science network: about 25-30 citizens will be selected per country and will be trained (introduction training Y1 followed by annual refreshment trainings (Y2-3) to conduct weekly monitoring of snail community and selected ecological parameters (Y1-Y4). Citizens will be selected during a pilot study following several criteria including gender, occupation, leadership skills and social status, in order to represent the community. In DRC it will be opted for the so-called 'relais communautaires' (community volunteers, who devote part of their time to activities of community interest, bridging community and health services), as the previous research showed they are well placed due to their background, connections and affinity with the area and the inhabitants. A joint young researcher will be appointed by ATRAP and HARISSA (department of Earth Sciences, RMCA) to monitor the impact of the citizen science network.

R2: The scientific community is informed on the distribution and drivers of snail-borne diseases in southwestern Uganda and Bas-Congo.

Activity 2.1. Organization of networking and research dissemination events (Y1,3,5): A kick-off meeting including national and international partners, experts, students and key stakeholders is organized at the start of ATRAP to introduce everybody, and discuss the detailed planning (Y1 in Congo and Uganda) and where each PhD student will present his/her proposed work plan. This is repeated in year 3 while the final meeting at the end is organized in Uganda for all partners.

Activity 2.2. Participation in international conferences (PhD 1-5; Y2,3,4): Scientific results will be communicated by PhD students and partners at national and international conferences. Likely conferences: 21th International Conference on Medical Geography and Public Health, Amsterdam, The Netherlands, May 2019; 11th ICT4D Conference information & communications Technology for Development, in Kampala, Uganda, May 2019; The annual meeting of the American Society of Tropical Medicine and Hygiene, November 2020 in New Orleans, USA; the biennial Africa Regional Conference of the International Communication Association (place and dates for 2020 to be confirmed), amongst others.

Activity 2.3. Participation of staff and students in scientific meetings and training sessions (all PhD students and MSc students Y1-4). Suitable workshops and short trainings will be selected to guarantee continuous skilling of students and staff.

Activity 2.4. Construction of web pages for MUST, UNIKIN and RMCA on their personal website providing information on ATRAP objectives with up-to-date maps on snail and parasite distribution (risk of infection) and general information about snail-borne diseases ((do's and don'ts) and methodologies for research in data-scarce settings. These web pages will be regularly updated after milestones.

Activity 2.5. Preparation and publication of manuscripts in peer-reviewed journals: It is expected that the multi-disciplinary approach will be relevant for other regions with similar challenges related to schistosomiasis infection. Therefore, attention is devoted to publish in peer-reviewed scientific journals. All researchers will contribute to this action.

R3: The knowledge and awareness of local communities on snail-borne diseases is improved, which could lead to behavioural change that reduces (exposure and thus) infection.

Activity 3.1. KAP surveys: About 600 households in DRC and Uganda (selected in small pilot survey) will be invited to participate in a survey (Y1; PhD 1, MSc1 and facilitators) and with a selection of households additional focus group discussions will be organized. The survey will measure current knowledge on prevalence, risk factors, cure, attitudes and behaviour with regard to snail-borne diseases and related determinants. The focus-group discussions will further probe underlying motivations and environmental factors (e.g. media use) adding richer contextual insights to the quantitative measures. Descriptive and multivariate analyses for the survey and thematic content analysis for the focus groups will be carried out to analyse the collected data (Y2). Finally, a quantitative post-intervention survey is carried out to monitor the impact of the citizen science outreach activities (PhD 1; end of Y3, start Y4). In DRC special attention will be paid to how people respond to the presence of snails in terms of myths, rituals and science. The strategy has a diachronic approach as it is considered that these beliefs and practices are dynamic, and respond to ecological, socio-economic and political changes (Y1; PhD 3, MSc3). In a later stage, the intervention of other team members and educational practices by the citizen scientists will be considered a case study in order to assess how alternative narratives and practices about snails and snail-borne diseases are interpreted, accepted and/or rejected. As such, the reception of and negotiations with scientific discourse about snails will be ethnographically studied (Y4; PhD 3).

Activity 3.2. Optimization of educational tools: Based on the outcome of the study in 3.1 in year 1 (identification of knowledge gaps, beliefs, misconceptions, vulnerable groups), existing educational material will be optimized, new materials will be (co)-created and contextualized with the citizen scientists (Y2) and used in the annual awareness week campaigns (Y2,3,4) organized by the citizen scientists and university staff and students (see above).

Activity 3.3. Training citizen scientist in educational activities): yearly trainings will be organized by local institutes and experts in communicating the transmission, risks, clinical signs, treatment and prevention of snail-borne diseases to the local communities. These yearly sessions are also meant to refresh the methodologies to collect snails and ecological parameters, and group bonding (Y2,3,4). A project assistant will be appointed by MUST, UNIKIN and RMCA for managing daily the citizen science database, the interactions with citizen scientists and stakeholders and for planning meetings and workshops. Citizen scientists will be given the tools to disseminate this information to the wider public (e.g. posters, leaflets, info-graphics/videos on their smartphones) and will be trained for effective communication strategies (e.g. use of narratives, persuasive messages, etc.).

Activity 3.4. Outreach activities in communities and online: organization of annual 'awareness week' campaigns, citizen scientists & students will be recognized through T-shirt with ATRAP logo; communication through radio, social media and websites of MUST, UNIKIN and RMCA.

R4: The local governments obtain a better knowledge on the existence of putative and on-going transmission sites of snail-borne diseases that affect humans, livestock and wildlife, allowing for targeted (snail) control in combating neglected tropical diseases.

Activity 4.1 Policy briefs are formulated based on the scientific outcomes including snail and parasite distribution maps, risk assessment models and spatial decision support systems for snail control. Recommendations are formulated to improve early disease detection Knowledge transfer on risk assessment models and capacity building for the practical implementation of spatial decision support systems is provided through manuals and 4.2 (Y3, 5).

Activity 4.2 Knowledge transfer through the organization of workshops for local health officials and key stakeholders in network events (Y3 and Y5).

R5: A strong multi-partner network on snail-borne diseases is created

Activity 5.1. Set up specific multi-partnership network centred around snail-borne diseases through regular networking events (see above, in Y1,3,5), participation of ATRAP partners and students in national and international scientific conferences (Y2,3,4).-

Activity 5.2: setting-up scientific workshop with national and international scientists, experts, students and key stakeholders within the kick-off meeting at the start and the end of ATRAP to introduce everybody and co-create contextualized research strategies. During the final symposium outcomes will be presented and future collaborations and follow-up studies will be planned.

Self-evaluation: Citizen science is at the heart of ATRAP as well as HARISSA (see SO3) activities. An evaluation of these innovative citizen approaches and their impacts (perception) both at the community and policy level, but also at the management level will be the subject of a specific study shared with ATRAP. The outcome will also provide the necessary feedback in order to streamline and possibly re-adjust the research strategy wherever needed. It is also anticipated that the design of the communication/awareness actions during ATRAP can be improved. An expert in citizen science is involved as partner.

f) Developmental relevance of ATRAP

Vector-borne diseases have a huge socio-economic impact. An estimated 1.5 billion disability-adjusted life years (DALY) are lost due to schistosomiasis alone, of which 77% in sub-Saharan Africa (Gryseels et al., 2006). Global prevalence estimates of human fasciolosis vary from 2.4 to 17 million people infected while global economic losses due to *Fasciola* infections in livestock are estimated to be over 3.2 billion US$ per year.

The citizen science approach will increase the long-lasting impact through active involvement of the communities at risk. Also, projects with a multi-partnership approach appear more effective than vertical control programs in terms of sustainability and empowerment of communities. A multi-stakeholder workshop will be organized at the start, the middle and end of ATRAP. These regular exchanges between the relevant stakeholders are key for evidence-based policy development and solid network construction.

g) Sustainability of ATRAP

Challenges for sustainability after DGD funding

Due to the strong academic curriculum of MUST and UNIKIN/INRB and the increased expertise, human capital and scientific network we are confident that ATRAP will lead to new opportunities to successfully attract funding to continue research in snail-borne diseases. However, a few challenges can be formulated:
1) retaining and expanding the academic capacity that was build up during the course of ATRAP
2) maintaining a high level of awareness in the communities and a sustainable change in risk exposure behavior.

Strategy to tackle those challenges

Sustainability of the academic outcomes

A microbiology and parasitology programme started at Biology Department at MUST to continue with academic and research capacity building in the area of medical malacology and vector-borne diseases such as schistosomiasis. ATRAP will increase the number of trained staff and PhD and MSc graduates, thereby boosting the involved departments. It will thus build the urgently required new research capacity for the local research partners. The workshops and the training students are tangible steps taken by ATRAP to ensure the sustainability of the academic

benefits. The team will continue to seek opportunities to continue the ongoing exchange of research expertise, and sharing of subject-based knowledge.

As part of its collaboration with the National Malaria Control Program, the UNIKIN Medical Entomology Unit regularly organizes the training of laboratory technicians and entomologists. After the training of the researchers in malacology, this activity will be extended to the national program for NTDs control in order to strengthen capacities of technician at different levels of the health system.

Sustainability of the developmental outcomes:

Upscaling of interventions by involving local government and NGOs as stakeholders especially for dissemination would be an asset. Through health education for behavioral change to open defecation and medicine uptake, the local population will be equipped with the necessary tools and knowledge to respond to the social challenges to schistosomiasis in a sustainable way: better medicine uptake, better sanitation, and presences of snail control measures.

Through workshops and closure meetings in the last 2 years of ATRAP, these tools for sensitization and education will be provided as 'out-of-the-box' packages for community awareness raising which can be used after the project's finalization.

h) Key stakeholders

Southern stakeholders

- **Vector Control Division (VCD), Ministry of Health Uganda**
  Interest & influence*: Critical. VCD provide a service for the protection of the health of the people of Uganda from vector borne diseases through the application of safe, effective, appropriate and sustainable vector control measures. It runs an integrated program to control and/or eliminate Neglected Tropical Diseases (NTDs) including Schistosomiasis (Bilharzia). It has personnel headed by Assistant Commissioner Health Services (Vector Control) with Medical Entomologists, Parasitologists, Medical Officers and Vector Control Officers in all districts hospitals and health centres at sub-counties.*

This key stakeholder will be invited right at start of ATRAP activities during the kick-off workshop in order to discuss the workplan and to participate in the oral presentations. They will be consulted throughout the project and invited for the closing workshop where the results will be presented.

- **The National programme for the control of NTDs, DRC**
  Interest & influence: *This program has doctors, lab technicians and a vector control unit that does not currently work. This program implements MDA to control morbidity due to schistosomiasis, soil-transmitted helminths and filariasis in at-risk groups including school-aged children. This activity is organized thanks to a prior mapping of the infection prevalence. For the program to target schistosomiasis transmission, a mapping of the distribution of mollusc species and risk of transmission is currently needed.*

This key stakeholder will be invited at the start of ATRAP to participate to the workshop and to align the working plan with actual needs of the program. The program will synchronize some of its field works so that lab technicians can be trained to malacological field works. The outputs of ATRAP will be shared with the national program in order to help the program adjusting its current control strategies.

- **MSF/Epicentre in Mbarara at MUST**
  Interest & influence: *High. Epicentre in Mbarara is created to support MSF projects in the region. It conducts clinical research following Good Clinical Practice (GCP) requirements on critical public health burdens in Uganda and Africa with a laboratory with a biosafety level 3. The laboratory is equipped to do mycobacteriology, perform GeneXpert TB tests, PCR, and routine laboratory analyses.*

Staff of epicentre can be included as stakeholders and the Epicenter has experienced team of doctors, nurses, statisticians, biologists, laboratory technicians, logisticians, and administrators

who ensure the quality of the research and are very keen on study of parasitology. They can be invited to ATRAP workshops, during dissemination of results and participate in the oral presentations. They will be consulted on scientific aspects of public health in course of the project implementation.

- **Local NGOs working on health education and WASH** (*Water, Sanitation and Hygiene)* **in DRC**
  Interest & influence: High. *Several NGOs work close to the community and have been involved in the promotion of health education and WASH activities in rural areas. This includes NGOs that collaborated in the "village assaini" program, funded by UNICEF*

This stakeholder will also be invited in the workshop that will be organized at Kimpese. They will be invited to share their experience and also to learn from the approach used by ATRAP.

- **Local governments (community leaders) and Village Health Teams (VHTs) Uganda**
  Interest & influence: *High. Community wellbeing. VHTs are key in mobilising masses on health-related issues.*

Collaborating with the ATRAP team in sensitization of the local communities and training of citizen observers. Local leaders will be crucial in organising community activities like snail-borne diseases awareness weeks.

- **Local branch of international NGOs in Uganda and DRC**
  Interest & influence: *Medium to low.* ***Protos*** *is a development cooperation NGO promoting and facilitating better water management (see Synergies).* ***Vétérinaires Sans Frontières*** *and* ***Red Cross*** *work on treatment, prevention and sensibilisation of veterinary and human diseases.* ***SOS Kinderdorpen****: One of their goals is to increase awareness around poor hygiene disease spread.*

They will be invited as stakeholders in the workshops/meetings and they will be kept up to date on the research results (eg risk maps) methodology (eg inclusion of citizen scientists), and best practices

<u>Northern stakeholders</u>

- **Belgian branch of ENABEL, Protos, SOS kinderdorpen, Red Cross**
  Interest & influence: *Medium to High*

They will be invited as stakeholders in the workshops/meetings and they will be kept up to date on the research results (eg risk maps) methodology (eg inclusion of citizen scientists), and best practices. When desired, collaboration will be pursued.

B. AGROVEG

Agroecological methodology in VEGetable crops

Expected outcome 4B: *Farmers health and sustainable food production is improved through the development of an agroecological methodology that mitigates the impact of fruit flies on vegetable crops (in Mozambique and Tanzania).*

Countries where the activities take place: Tanzania (Morogoro) & Mozambique (Maputo)

Summary

Horticultural crops can provide sustainable income and food security for African farmers. However, their production is hampered by the presence of several pests, among which tephritid fruit flies are a major concern. Pest control is currently done by indiscriminate, expensive and often inefficient use of pesticides, having a negative impact on the farmers' health and on their environment. AGROVEG proposes the development of an environmental friendly methodology, along agroecological principles, to mitigate the impact of fruit flies on vegetables that are biologically fruits such as cucurbits and solanaceous crops. This agroecological approach aims at strongly reducing the impact of control methods on the ecosystem while having a positive effect on beneficial organisms such as pollinators. Through this contribution the local partners will strengthen their research units and further enhance their expertise with regard to fruit fly (FF) pests and their control.

Keywords: Agroecology, Cucurbitaceae, Solanaceae, Tephritidae, pest control, food security

DAC sector code & policy markers: 31182 &31192 / UR

Partnerships:

- Sokoine University of Agriculture (SUA), Morogoro, **Tanzania**
  Department of Crop Science and Horticulture
- Eduardo Mondlane University (EMU), Maputo, **Mozambique**
  Faculty of Agronomy and Forest Engineering

RMCA promoters:

Marc DE MEYER (Biology), Kurt JORDAENS (Biology), Massimiliano VIRGILIO (Biology)

a) General context

Development problem that AGROVEG wants to tackle and its sectoral context

Main context

Nearly 805 million people worldwide were unable to meet their dietary requirement in 2010-2013. With 23.8% of the undernourished in sub-Saharan Africa, this is one of the hardest hit regions. Horticulture, being an important agricultural subsector in Africa, offers excellent opportunities for individuals to provide income, create employment, and enhance food and nutritional security. It is viewed as a major economic development strategy, especially as the demand for fruit and vegetables continues to grow both on the domestic and international market. However, fruit flies (FF, Diptera: Tephritidae) are responsible for both direct and indirect losses, with alien invasive species often having the most severe impact. While tremendous efforts have been deployed in Africa over the last decades on mitigating the impact of these pests on (sub)tropical and temperature fruit crops (mango, citrus, guava, stone fruits) far less emphasis has been put on vegetable crops. However, several are biologically fruits such as cucurbits (pumpkins, courgettes, gourds) and Solanaceae (tomatoes, bell peppers, eggplants) and suffer dramatic losses due to tephritid FF infestations. Moreover, the horticultural industry focuses on pest control through an often indiscriminate use of conventional pesticide applications with negative implications on the farmers' health, the consumers and the environment, which could result into pests' resistance and resurgence.

Problem analysis

Problems related to the pests

Africa is home to about 400 fruit infesting Tephritidae, attacking a wide variety of wild and commercial plant hosts. Of these, approximately 30 are considered of major economic significance, causing substantial losses to fruit and vegetable production. While the majority of these pest species are indigenous, over the last decades Africa has known invasions of alien species (predominantly from Asia) aggravating the economic losses and impact caused by FF pests. Some of these alien invasive species invoked disastrous reductions in crop production.

Problems related to farmers' approach

Farmers (in particular small-scale) have limited knowledge to adequately control pests on their crops. They are conscious of crop losses but often don't have the know-how on what is causing the damage and how it can be controlled in an efficient way. As a consequence they apply a range of insecticides indiscriminately, often based on a calendar schedule rather than outbreak predictions, or applied too late in the infestation process. These insecticides, thus, do not always have the desired effect. The indiscriminate use of pesticides has negative consequences. It poses a danger to the health of the farmers they are used without the appropriate security precautions. There is neither awareness on this, nor on the possible negative effects on the environment. Substantial amounts of the insecticides end up in the environment and disrupt local eco-services (*e.g.* natural predators, pollinators) with further loss in production. They have an impact on the ecosystem as a whole (*e.g.* contamination of drinking water, disruptive effects on physiological processes, etc.) and affect the health of other humans (consumers, but also inhabitants of the adjacent areas). It also has financial implications as pesticides come at a certain price and farmers rely on these, putting them in a vulnerable position against the industry. Small-scale vegetable production is predominantly conducted by women, making this gender thus more vulnerable to income loss and poor health.

Problems related to legislation and governance

The governments of most African countries are lacking an adequate surveillance system in order to monitor the distribution and spread of these pest species. They also lack effective control measures to avoid unwanted introductions of pest species. In addition there is little to no regional approach at governmental level to this problem, resulting in trans-border dispersal and inadequate reporting of pests because of the fear of trade restrictions. Most governments also lack appropriate legislation, as well as the means to implement existing legislation with regard to pesticide use. While the authorization to bring particular insecticides on the commercial market is usually well regulated and controlled, there is no real follow-up on how the pesticides are actually used, what the effects are on the environment, and whether pesticide residues are reduced adequately before crops are being sold at the market.

Problems related to research

A lot of emphasis has been placed in recent decades on African tephritid pests of actual fruits, mainly because of the high demand in the developed world for (sub)tropical fruits and the associated trade and export market issues. We have a fairly good understanding of the distribution, host range, interspecific competition, and infestation rate of the main fruit pests. Also a number of control methodologies (mainly using Integrated Pest Management) have been developed for some crops such as mango. However, for vegetable infesting FF, the knowledge is much more restricted. For most of the cucurbit and solanaceous feeders the basic ecological information is lacking and appropriate control methods, tuned to local conditions, are not developed. As a consequence researchers can neither address queries or demands from the industry to provide scientific expertise in this domain, nor offer farmers an adequate alternative to conventional control methods.

Capacity constraints and needs of the partner institutions

African research institutions, including the AGROVEG partner institutions, have been implementing FF related research and have a certain expertise available in this field. However, as stated above, this is mainly with regard to fruit infesters and not so much on FF pests of vegetable crops. Moreover, regarding the use of environmental friendly control methods, there is little

information available. Agroecology merges ecological knowledge with pest management, by studying the interactions between plants, animals, humans, and their environment within agricultural systems. As such, it leads to a safe and environmental friendly crop protection. Reducing pest populations and increasing numbers of natural enemies and beneficial insects, such as pollinators, are an essential part of the agroecological approach. An agroecological approach would thus be an appropriate method for mitigating the impact of FF pests of vegetable crops, and research programmes in La Réunion have shown their effectiveness.
The partner institutions are aware of the potential advantage of agroecological methodologies and invest in research disciplines focusing on this aspect. SUA is launching a PhD programme specifically in agroecology. EMU explores inclusion of a short term course on agroecology in their MSc programme. Yet, currently they lack the necessary means to fully develop this research field.
Over the years, RMCA has been collaborating with both SUA and EMU and invested largely in capacity building regarding expertise on FF research and management (cf. background below, and evaluation report on North South South collaboration with SUA and EMU (2018)). However, agroecological research, in particular with regard to FF and vegetable production, is a novel field and given the above mentioned initiatives taken by the local partners a further reenforcement is required.
AGROVEG will enhance their role as centres of excellence on FF research and control, allowing them to obtain expertise in new research methodologies and in the meantime strengthen the educational programmes they offer. It would allow them to contribute to agricultural practice improvement in their countries, providing scientific ground for recommendations to policy makers.
The current research capacity, available at the local partner institutions, will be further increased by one PhD and several MSc researchers (pending commitment by the partners to include these persons in their research units).

b) ***Background***

Partnership/ownership

Over the last decade the RMCA has developed a strong collaboration with both the SUA and EMU partners in the field of research on FF pests. Both institutions are recognized educational and research institutions in their respective countries with regard to agriculture. They have been actively involved in FF research activities over the last decade or more and have an active research unit specifically dedicated to FF management (see under 'previous experiences,…' below). Most of these activities have been focusing on fruit production (both large and small scale) and how to reduce the impact of both indigenous and exotic invasive FF pests on a number of (sub)tropical fruit crops. This has led to a considerable research output and a number of applied tools and services such as a pest management manual for Tanzania, recommendations to the Mozambican government, joint project proposals (including NSS collaboration), and training of researchers at MSc and PhD level.
Less attention in the research has been paid to vegetables which, from a biological point of view, are considered as fruits. Only some limited exploratory studies were started. Nevertheless, these crops are also susceptible to infestation by tephritid FF. This knowledge gap was discussed with the partners on several occasions over the last two years. In addition, the issue has become more relevant due to two events: the further spread of the tomato FF (*Bactrocera latifrons*), which was first recorded in Africa in Tanzania in 2006 and an increase in dispersal of an ancient introduction of the melon FF (*Zeugodacus cucurbitae*) into the northern parts of Mozambique.
These factors combined, and the interest of SUA on development of agroecological expertise, initiated the continuation of the North-South-South collaboration, through AGROVEG. Initial ideas were discussed during meetings in Morogoro and Tapachula (Mexico) this year and through skype conference.

Previous experiences between the partners

From 2004 to 2012 collaboration with SUA on FF through two multiannual RMCA-DGD programmes, with emphasis on biology and control (through Integrated Pest Management - IPM) of FF pests in mango. Since 2013 a focus was given to knowledge transfer from SUA to EMU, through North-South-South collaboration, including improvement of the IPM program. Since 2015 SUA is active in organising a local training programme on taxonomy and basic ecology of African FF (prior involvement of SUA staff in training programme since 2009).
Collaboration with SUA and/or EMU within framework of programmes initiated by IAEA (International Atomic Energy Agency): Regional Project RAF5074 (2016-2019); Coordinated Research Project on Cryptic Species (2010-2015); Research contract on origin, distribution, host plants and interspecific competition of *Bactrocera latifrons* (2007-2008). Collaboration with SUA and EMU in BELSPO monitoring network for FF in Southeast Africa (2013-2017). Collaboration with EMU in USDA/APHIS surveys on spread of *Bactrocera invadens* (2008-2010); STDF (Standards and Trade Development Facility) project preparation grant for establishment and maintenance of fruit production areas free and under low prevalence of FF pests (2017-2018)

Major achievements of these collaborations are that both RMCA, SUA and EMU form a strong collaborative network, that SUA and EMU are recognized as regional centres of excellence regarding FF research and management, and that a number of PhD (2) and MSc (3) students have been trained in both countries, specialized on FF research.

c) ***Theory of Change***

The overall desired change envisaged through AGROVEG is that it contributes to local (small-scale) farmers having a larger output of vegetable crops free of FF pests and practising a cultivation with less environmental impact. This change is desirable because higher crop output means more food security, more income, and better health for the farmers. As small-scale vegetable production is predominantly conducted by women, it would contribute to improvement of position of women in rural farming communities. Less environmental impact means less loss of biodiversity, less ecological damage, resulting in a better health of both the farmer and consumer. As such, AGROVEG is considered important for the farmers involved in vegetable production but also for the consumers and those living in and relying on the same environment.
Given the existing expertise of the partners, their research emphasis and the funding and time limitations, only a number of factors listed in the problem analysis can be tackled directly through AGROVEG. The following topics are selected as being of high priority in order to contribute substantially to the desired overall change:

- ✓ *Problems related to the pest:* Have a better understanding of a number of biological aspects of the target pest FF
- ✓ *Problems related to the farmers' approach:* Have a better understanding of the awareness among farmers with regard to damage inflicted by pest FF, and provide farmers an alternative methodology to control FF damage in vegetable crops, that is based on environmental friendly practices
- ✓ *Problems related to legislation and governance:* Provide policy makers scientific data that will allow them to consider implementing environmental friendly horticulture practices
- ✓ *Problems related to research:* Develop the technical and scientific support to enable partner institutions to gain the necessary expertise with regard to FF vegetable pest biology and control, in addition to pollinators' diversity and genetic research.

As outlined in the general RMCA strategic plan, these topics are addressed at several levels and through several spheres.

Within the sphere of control, RMCA will develop activities in synergetic collaboration with partners in the South and the North, mainly considered as scientific actors/stakeholders: local universities (SUA, EMU), European research groups (RBINS, CIRAD) and technical actors/stakeholders (ONGs).
Within the sphere of influence the following target groups are envisaged: the farmers affected by the FF pests and the researchers affiliated with the local institution.

Regarding farmers the following phases have to be followed:
Initial phase: perception of farmers regarding the FF pest problem. Are they aware of what is causing damage? Do they make the relationship between infested fruits, larvae found inside the fruits that are causing the rotting, and adult flies found in the garden plots? How severe do they consider the problem?
In a second phase: how do they tackle the problem (if at all)? What measure do they take (sanitation, pesticides, others)? Do they know the impact of these measures on the mitigation of the FF pest problem? Are they aware of any negative facts caused by these measures? Information on these two phases will be obtained through surveys and questionnaires.
This perception by the farmers need to be complemented by actual data on FF impact. The following questions need to be answered: What are the main pest species and their occurrence both in time and space? What is the impact of these pest species on the actual crop production and losses? The local researchers require the means to obtain this information. This will be acquired through surveys (mainly targeting the current spread of invasive exotic species in both countries) and through sampling (by trapping and rearing) at selected experimental sites.
Once the information is obtained on both accounts, an environmentally friendly control method will be developed. This will be based on agroecological principles where a combination of push-pull strategies, selected trapping, and orchard sanitation will be applied. These agroecological methodologies will be compared with conventional control strategies applied by the farmers, both in terms of effectiveness and cost. In addition, the impact of both methodologies on beneficial insects, in particular pollinators, will be investigated.
The acquiring of baseline data, and the development of environmentally friendly control measures will simultaneously enable the local partners to enhance their training programs and re-inforce their research capacity. This will include: enhancement of local research infrastructure; training through MSc and PhD programs, development of a specific training course on pollinators. As such it will increase the local expertise and regional recognition as centres of excellence.
The developed agroecological methodology will then be transferred to the farmers community (directly to farmers and indirectly through extension officers). This will be done through the development of demonstration plots, through the publication of information brochures explaining the methodology, and through the organisation of group training sessions. In addition the pest management strategy will be advocated to policy makers like government official, extension officers, NGOs, etc. through policy briefs.

The expected changes can be divided in <u>immediate changes and intermediate changes.</u>

Immediate changes are linked to:
Sensibilisation:
Farmers will recognize the impact FF have on their crop production, and will be aware of the alternative environmentally friendly control methods and its advantages.
Knowledge gathering:
Local partners have trained students and researchers and obtained expertise and research infrastructure to study aspects related to FF biology and agroecological methodologies to control pest FF on Information on FF biology and agroecological methodologies is disseminated to the farmers community and to policy makers.

vegetable crops.
Competence gathering:
Researchers at local institutions will have gained additional expertise regarding FF control and will be in a better position to provide advice on matters regarding pest FF and mitigation of their impact.

Intermediate changes have to be categorized as
Good governance
Farmers adapt the agroecological methodology resulting in a higher production and less crop losses, with less impact on the environment.
Diffusion of knowledge
Research results are presented to the scientific community and to relevant decision and policy makers
Structural and operational re-enforcement
Local partners continue to produce relevant research with regard to FF pest and their control.
Communication
Research results are presented to relevant decision and policy makers
International recognition
Local partner institutions are further recognized as international centres of excellence with regard to FF management.

As such, AGROVEG will contribute to a higher quality and more sustainable mode of living for the beneficiaries, along the strategic lines set out by the general strategic plan, in particular with regard to contributing to the sustainable development goals.

d) ***Expected results***

R1: Strengthening scientific research capacity
Research on biological data of FF pests and agroecological control methodologies in vegetable crops, with emphasis on cucurbits and solanaceous crops, is conducted in order to increase production and mitigate loss in an ecological sound manner. Four MSc and one PhD researchers are trained in aspects related to agroecology. Local research teams will be further strengthened and obtain additional expertise on FF related matters.

R2: Strengthening physical and virtual diffusion of scientific research results to the larger scientific community
Research results are published in international peer reviewed journals and presented at dedicated international conferences. Existing websites on FF pests and pollinators are enhanced. Group training on pollinators is provided.

R3: Awareness raising towards the general public
Farmers are trained on agroecological practices in vegetable plots. Educational tools on agroecological practices in vegetable plots are developed.

R4: Support to good governance, based on the scientific results
Policy brief on agroecology in horticultural production is composed and information disseminated to relevant governmental parties and other stakeholders.

R5: Development of synergies and complementary activities among partners through multi-partner governance and coordination
Meetings with other partners involved in horticultural research in Africa are organized.
The planned activities and results obtained are mainly resulting in a contribution to SO4, with some implications also for OS1. As such they link up with the following Sustainable Development Goals:

SDG 2 (Zero hunger): assisting farmers in obtaining higher yields, by mitigation of agricultural pests, will contribute to a higher food production. It will also provide a higher income to the farmers which will allow him/her to invest in better health (SDG3) and education (SDG4).
SDG 15 (life on land) & SDG 14 (life below water): agroecology is geared towards a more environmental friendly approach of agricultural production. As such it will reduce the use of harmful products such as pesticides that have a negative impact on terrestrial and aquatic ecosystems.

e) ***Methodology***

R1: Research capacity

R1.1.Obtaining information on farmers' perception of pest status and their impact on production of vegetable crops, through a standardized survey (Y1)

Y1: survey Tanzania, Morogoro area and Mozambique, Manica and Maputo area, questionnaire approx. 90 farmers, 3-4 weeks, student assignment (BSc)

R1.2. National surveillance, spread of B. latifrons/Z. cucurbitae (Y1-5)

Four missions in Tanzania, and five missions in Mozambique of 10-15 days each, through setting out trapping network over transect, and collecting potential hosts (joint SUA/EMU/RMCA team)

R1.3. Seasonal abundance and host preference (Y1-2)

Cucurbit/Solanaceae growing farms (2/country): cuelure and protein bait traps, malaise traps, 2 annual cycles (Y1-2). Regular collection potential hosts, infestation rates. Field observations flower visitors/pollinators (3MSc)

R1.4. Host related transcriptomics (Y3-4)

Laboratory experiments at SUA of *Z. cucurbitae* fed on allegedly optimal and suboptimal hosts. Extraction of larvae and analysis of larval transcriptomes (1MSc)

R.1.5. Developing trials for testing agroecological methods (Y2-5)

Experimental plots at SUA to compare conventional methods for pest control versus agroecological methods with particular reference to sanitation, deployment of traps, soil improvement, intercropping and push-pull methods, and their impact on populations of pest and beneficial insects and on crop production (1PhD, part of SUA PhD agroecology program).

R.1.6. Supporting PhD and MSc researchers

Support of 1 PhD and 4MSc students (cf R1.3-1.5)
Thesis topics for 6BSc students (cf R1.1, R1.2, R4.2)

R2: Diffusion to scientific community

R.2.1. Participation at international conferences (Y2, Y4)

Participation at three international scientific conferences of SUA/EMU/RMCA members of staff and students linked to AGROVEG, to present AGROVEG results and interact with fellow researchers:
Y2: 4th International TEAM Symposium (France, 2020)
Y4: XIth International Symposium on Fruit Flies of Economic Significance (Australia, 2022)
Y4: Participation at the 3rd International Symposium on Agroecology (Rome, 2022)

R2.2. Publication of research results, to disseminate the results to the larger scientific community (Y3-Y5)

Three to five public access publications (peer review journals, conference book of abstracts and proceedings, chapters in books, etc.) each during Y2 tot Y5 with AGROVEG results.

R2.3. Enhancement of existing websites on fruit fly pests and pollinators (Y2-5)

Extension of existing factsheets http://fruitflykeys.africamuseum.be/;)
Additional information distribution http://projects.bebif.be/fruitfly
Additional images digit03 website http://digit03.africamuseum.be/home
Additional information pollinators (https://www.pindip.org)

R2.4. Organisation of training course (bi-annual) on dipteran pollinators (Y1,Y3,Y5)

Training course on pollinators, two weeks, 12 participants,

To be organized 3 times (Y1, Y3, Y5) (joint SUA/RMCA team & externals)

R3: Awareness raising

R3.1. Demonstration sessions to farmers on methodologies tested throughout the project (Y4,Y5)

Y4: Development demo site in Mozambique near Maputo (in Tanzania the SUA orchard site where experiments are conducted, can be used)

Y4: Demonstration session (one day) for 20-30 farmers: 1EMU, 1SUA

Y5: Demonstration session (one day) for 20-30 farmers, 2EMU, 2SUA

(SUA and EMU teams respectively)

R3.2. Development of educational tools for the farming communities showing different agroecological implementations (Y4-5)

Y4: development manual (20-30 pages), 500 copies (250 Kiswahili, 200 Portuguese, 50 English), to be distributed during demonstration sessions and at other events

(joint SUA/EMU/RMCA team)

R4: Support to good governance

R4.1. Development of policy brief on agroecological methods and their impact, to be distributed to policy makers and other stakeholders (Y4-5)

Y4-5: development of policy brief by CEBios unit at Royal Belgian Institute of Natural Sciences.

(50-100 copies Kiswahili, 50-100 copies Portuguese, 50 copies English)

(joint SUA/EMU/RMCA team)

Y5: presentation of policy briefs to relevant governmental institutions

R4.2. Cost benefit analysis of agroecological approaches in production of cucurbit and solanaceous crops (Y5)

Y4: Comparison costs-benefits between conventional control versus agroecological approach, including crop losses, price control methods, labor, etc.

(BSc School of Agricultural Economics and Business Studies (SUA) and Department of Agroeconomics and Faculty of Economics (EMU))

R5: Development of synergies

R5.1. Interaction with other partners involved in agroecological practices in Africa (Y1-Y5)

Y1: Visit by SUA/EMU/RMCA staff to CIRAD La Reunion, to interact with CIRAD researcher

Y2: visit of CIRAD researcher to Tanzania, to provide input for PhD research

Y3/Y5: follow up visit of CIRAD researcher to Tanzania, regarding PhD research

Y2, Y4: participation at international conferences (cf R2.1)

R5.2. Stakeholder, actor, policy makers workshop (Y5)

Y5: two day workshop at SUA with 30 participants for interaction with other entities working on agroecology

f) Developmental relevance of AGROVEG

Mozambique

In Mozambique, agriculture is the most important employment sector, employing 80% of the workforce and accounting for 20% of GDP. The Action Plan for Reducing Absolute Poverty (PARPA) envisages agriculture and rural development as one of the strategic priorities to fight poverty, and improvement in horticultural revenue is an essential part of this. The Mozambique Diagnostic Trade Integration Study (DTIS) specifically recommended a sector development strategy that focuses on diversifying into higher value product lines and other export markets with horticultural export as the principal example. The subsequent crop diversification strategy promoted both by the government of Mozambique and the private sector, led in recent years to a production growth of fresh fruits and vegetables. Mozambique as such has an enormous potential for export of horticultural produce. Vegetable crops have a high potential in this regard

but require adequate pest control. Therefore, AGROVEG directly addresses the enhancement of sustainable agricultural productivity, and export opportunities (Decreto n° 05/2009).

Tanzania

Agriculture is the backbone of the Tanzanian economy. The sector employs majorities of Tanzanians, mostly residing in rural areas. As such agriculture is the forefront of fighting poverty among populations. AGROVEG is aligned to the objective of Tanzania's Development Vision 2025 *i.e.* to contribute to the national economic growth, reduce rural poverty and improve food security and nutrition in Tanzania. The outputs will contribute to transformation of the agricultural sector towards higher productivity, commercialization level and smallholder farmer income for improved livelihood, food security and nutrition in line with Agricultural Sector Development Programme Phase II (ASDP II). AGROVEG is aligned to Tanzania's National Research and Development Policy (URT, 2010); Research priorities for Tanzania 2015 – 2020; Agriculture resilience plan 2014 – 2019 and; The Agriculture First Resolve (Kilimo Kwanza, pillar number 8), National Strategy for Growth Poverty Reduction (MKUKUTA).

In the long term AGROVEG will a) consolidate the expertise on FF of the local partners as well as RMCA; b) contribute to an improved crop production, and protection and thus food security; c) contribute to providing alternative environment friendly control methods; d) increase the research potential of the respective countries.

g) Sustainability of AGROVEG

Challenges for sustainability after DGD funding

The local partners have shown to be able to sustain research independent from the projects funded by Belgian Development Cooperation. They have been capable of attracting funding independently. Through the novel expertise they will acquire from AGROVEG, they will have an even stronger position to be part of research consortia, and to request for funding. By transferring horticultural methodologies which require limited financial input, to the farming community, there is a high likelihood that they will be implemented in a sustainable manner.

Strategy to tackle those challenges

Research institutions in developing countries also face the challenge of obtaining sufficient funds in order to continue their research. In order to ensure continuation of the research agenda of both SUA and EMU both institutions will develop the strategy of looking for alternative funding during the second half of the project's lifetime. Both institutions have a track record of being able to attract funding for research opportunities in their field of expertise.

h) Key stakeholders

Southern stakeholders

- **Young African researchers and students (emphasis on female participants)**
  Interest & influence: *critical*

Young researchers and students will be given the opportunity to be directly involved in AGROVEG activities, and obtain expertise and knowledge. Their involvement is critical for proper execution of all activities.

- **Local farmers (emphasis on female farmers)**
  Interest & influence: *critical to high*

Involvement of some farmers is critical in that they need to provide essential information on the case studies, provide access to their farms and allow research conducted in their fields. The farmers community also benefit directly from the knowledge attained.

- **NPPO, government officials**

Interest & influence: *medium*

NPPO's and government officials involved in plant protection, will be informed and involved in processes where appropriate

- **Other research institutions (ministry, international) and local NGO's**
  Interest & influence: *medium to low*

Local or regional research institutions and NGO's will be kept informed on AGROVEG results. Where applicable (and participation as actor is feasible) collaboration can be envisaged.

Northern stakeholders

- **Belgian or other northern NGO's**
  Interest & influence: *medium to low*

Belgian or northern NGO's active in the field of agroecology will be informed on AGROVEG results. Where applicable (and participation as actor is feasible) collaboration can be envisaged.

C. DISPEST

Redefining DISpersal potential for adequate fruit fly PEST management (Diptera, Tephritidae)

Expected outcome 4C: *Agricultural productivity is increased through the development of an optimised pest management specifically calibrated for two common frugivorous pests (C. rosa and C. quilicii) in South and East Africa.*

Countries where the activities take place: South Africa (Stellenbosch), Mozambique (Maputo)

Summary

Ceratitis rosa and *C. quilicii* are two important agricultural pests occurring throughout South and East Africa. DISPEST aims at providing relevant information for the development of specific control strategies for these two species. It aims at collecting novel distribution, host preference and population genomic data and, using an innovative approach, at modelling their intraspecific patterns of connectivity and invasion routes. Through DISPEST the promoters will indicate areas suitable as Pest Free Areas (PFAs) and Areas of Low Pest Prevalence (ALPP) and will provide training to National Plant Protection Organisation officers so to increase capacity of early detection and monitoring of these common pests. Awareness on pest identification and control will also be raised involving farmers and growers associations. A MSc and a PhD student will strengthen the research capacity of the local partners and will further enhance their expertise on tephritid pests.

Keywords: agricultural pests, tephritidae, trapping, fruit rearing, population genetics, landscape models

DAC sector code & policy markers: DAC: 31182

Partnerships:

- Stellenbosch University, Stellenbosch, **South Africa**
  Department of Conservation Ecology and Entomology
- Citrus Research International, Nelspruit, **South Africa**
  Integrated Pest Management Portfolio, Fruit fly Programme
- Eduardo Mondlane University (EMU), Maputo, **Mozambique**
  Faculty of Agronomy and Forest Engineering

RMCA promoters: Massimiliano VIRGILIO, Marc DE MEYER (biology)

a) General context

Development problem that DISPEST wants to tackle and its sectoral context

Main context

The family of tephritid flies or "true" fruit flies (Diptera: Tephritidae) is widespread and comprises frugivorous parasites, causing major agricultural losses worldwide. These common agricultural pests contribute to economic losses with a diverse suite of potential socio-economic consequences. In Sub-Saharan Africa, damage on commercial fruits is caused by a relatitvely limited number of polyphagous species (approximately 30), mainly belonging to three genera (*Ceratitis*, *Dacus* and *Bactrocera*). In developing countries, the periodical frugivorous tephritid outbreaks significantly threaten food and nutritional security by reducing the availability of essential dietary components and putting at risk the income of rural small-scale farmers as well as of national and international traders. In addition to the direct losses caused by fruit fly infestations, indirect losses resulting from international quarantine restrictions can be enormous. For example, following the *B. dorsalis* invasion in 2003, Kenya lost its entire avocado (*Persea americana*) export market in South Africa, resulting in revenue losses of $1.9 million in one year (2007). Infestations of frugivorous flies are heterogeneous in space and time, and populations of the same species can infest different hosts in different locations and time periods. The distributions and abundances of frugivorous tephritid pests have been strictly related to human-mediated activities, such as agriculture, national and international trade of fruit and plant products, tourism, and movements of military troops and refugees. The risk of introductions of tephritid pests is a major concern since human-mediated processes have dramatically increased their potential for dispersal. Additionally, climate change is shifting the geographic distribution of many species, so that frugivorous tephritids can expand their distributions to formerly unsuitable or inaccessible regions. In this respect, a better understanding of the dispersal routes of the most impactant agricultural pests would greatly help their early detection facilitating the resulting management plans.

Problem analysis

Problems related to the pests

Ceratitis rosa and *C. quilicii* are two economically important African tephritid pests occurring throughout South and East Africa. Until recently (2016), these two taxa have been considered as a single taxon (*C. rosa*) but they are now acknowledged to be distinct species with partially overlapping distributions and ecological requirements (including developmental temperatures). However, there is little knowledge about how much these species differ in their ecological requirements and there is now an urgent need to gather additional information and to (a) reconsider and update their distribution maps and host range information, (b) re-evaluate the risks that each of them pose to different crops and horticultural industries (temperate, versus tropical and subtropical) and (c) define the extent of differences in their dispersal potential and putative invasion routes.

Problems related to farmers' approach

Control and management for both *C. rosa* and *C. quilicii* should urgently be reviewed by taking into account the ecological and distributional and host-range differences between these two species. The development of more efficient pest management plans would allow maximising farmers' efforts to reduce pest damage and, consequently, to increase fruit production.

Problems related to legislation and governance

As a result of collaborative research between, RMCA and Citrus Research International (CRI, South Africa), we developed a decision map and a simplified molecular diagnostic tool for the identification and monitoring of *C. rosa and C. quilicii*. However, the identification of these two pests is still cumbersome, and this reduces the possibility of efficient early detection and control of *C. rosa* and *C. quilicii.*

Additionally, the same quarantine restrictions previously applied to *C. rosa* are now applied to both *C. rosa* and *C. quilicii* without properly taking into consideration possible differences in host range, distribution and damage caused to fruit production. A more specific legislation would greatly help reducing the unnecessary economic losses generated by not fully calibrated action

plans and, in this respect, more detailed information about the ecology and distribution of *C. rosa* and *C quilicii* is necessary.

Problems related to research
Due to the recent split of C. *rosa* into *C. rosa* and *C. quilicii*, the distribution and host range of these two pests is only vaguely known and there is an urgent need for additional data to fill the current knowledge gap. A recent approach promoted, *inter alia*, by reseachers of Stellenbosch University (SU, South Africa) allows integrating existing pest distribution, and population genetic data with estimates of landscape connectivity (climate, vegetation, and topography) to generate predictions of the most likely dispersal pathways of target agricultural pests. This approach, that has not yet been applied to *C. rosa* and *C. quilicii*, also considers the intrinsic landscape barriers occurring in the target region, allowing the identification of appropriate management units and defining the spatial scale at which to apply control techniques.

Capacity constraints and needs of the partner institutions

SU already has a laboratory for molecular analyses as well as experience in the analysis of genetic data using more traditional genetic tools such as Sanger sequencing and microsatellite markers. However, up to date, SU still lacks substantial experience on the most recent and advanced molecular techniques (Next Generation Sequencing, NGS) including population genomics. DISPEST aims at performing NGS based collaborative research. In this respect, the local PhD, supervised by SU researchers, will be trained at the molecular laboratory at RMCA on genomic library preparation and analysis of High Throughput Sequencing data.

EMU and CRI already have a great deal of experience in field monitoring and pest management of tephritid fruit flies, but not much on ecological modelling. DISPEST promotes South-South knowledge transfer and capacity building between SU and EMU/CRI. With this aim, an MSc student attached to SU will collaborate to collect and analyse data at CRI.

b) ***Background***

Partnership/ownership

RMCA, SU, CRI and EMU are longstanding research partners and, over the last decade, were involved in a number of collaborative projects focusing on ecology and integrated pest management of tephritid agricultural pests. This resulted in the production of a number of peer-reviewed scientific papers dealing with tephritid pest taxonomy, ecology and distribution Recently, RMCA produced a decision map for the morphological and molecular diagnosis of *C. rosa* and *C. quilicii* (collaboration with CRI), a brief with recommendations to the Mozambican government on fruit fly pest management (collaboration with EMU) and joint project proposals (including NSS collaboration), and were involved in training of local researchers at MSc and PhD level.

DISPEST originates from the need of involving African partners with solid expertise in fruit fly research from an area which is crucial in the distribution of the two target species (South Africa and Mozambique).

The DISPEST project rationale and main concepts were discussed during meetings in Stellenbosch (South Africa) and in Tapachula (Mexico) earlier in 2018 and were finalised through email correspondence and Skype conferences.

Previous experiences between the partners

EMU

- Since 2013 knowledge transfer from Sokoine University of Agriculture (TZ) to EMU, through North-South-South collaboration in the previous RMCA-DGD multiannual program, including improvement of the Integrated Pest Management program.

- Collaboration with EMU within framework of programmes initiated by IAEA (International Atomic Energy Agency): Regional Project RAF5074 (2016-2019);
- Collaboration with EMU in BELSPO monitoring network for fruit flies in Southeast Africa (2013-2017).
- Collaboration with EMU in USDA/APHIS (United States Department of Agriculture Animal and Plant Health Inspection Service) surveys on spread of *Bactrocera invadens* (2008-2010);
- STDF (Standards and Trade Development Facility) project preparation grant for establishment and maintenance of fruit production areas free and under low prevalence of fruit fly pests (2017-2018)

SU

- STDF (Standards and Trade Development Facility) project preparation grant for establishment and maintenance of fruit production areas free and under low prevalence of fruit fly pests (2017-2018)
- Collaboration with SU in BELSPO monitoring network for fruit flies in Southeast Africa (2013-2017
- organisation 3rd International TEAM Symposium (2016), Stellenbosch, South Africa

CRI

- STDF (Standards and Trade Development Facility) project preparation grant for establishment and maintenance of fruit production areas free and under low prevalence of fruit fly pests (2017-2018)
- Partner ERAfrica Project "Detection methods for fruit flies of economic significance to fruit and vegetable production in Africa and Indian Ocean islands" (2014-2017)
- Collaborator Citrus Research International (South Africa) project "Developmental threshold and critical thermal limits for two *C. rosa* types in South Africa" (2013-2014
- Collaborator Citrus Research International (South Africa) project "Determine the potential global distribution for *Bactrocera invadens* using CLIMEX" (2011-2012)
- Collaborator Citrus Research International (South Africa) project "compilation of a fruit fly brochure and development of a rapid molecular identification technique for Bactrocera invadens" (2011-2012)

Major achievements of these collaborations are that RMCA and the above-described institutions form a strong collaborative network, that SU, CRI and EMU are recognized as regional centres of excellence regarding FF research and management, and that a number of PhD and MSc students specialized on FF research have been successfully trained in these countries.

c) Theory of Change

Desired change

The *desired change* of DISPEST is to increase agricultural productivity by facilitating the development of improved pest management plans specifically calibrated for two common frugivorous pests (*C. rosa* and *C. quilicii*) in South and East Africa. Optimised pest management will allow a more efficient use of resources allocated to pest control by both small-scale farmers and national and international traders. More efficient pest control will also provide higher food security and, if based on a more efficient use of insecticides and agricultural practices, will also be beneficial to the environment. Additionally, in small rural communities, women, who are often responsible for vegetable and fruit production, will more directly benefit of higher income and increased food security.

Domains of change

Based on the analysis of the current situation, three main groups of **stakeholders** can be identified:

- the local universities and researchers

- the local governments and
- the farmers and growers (from small-holders to national and international traders)

and the following two domains of change which are under the sphere of influence and represent the **specific objectives** of DISPEST:
(1) the local university's agricultural departments become more research active, stimulating more efficient pest control strategies in the agricultural sector (improved research practices)
(2) farmers and growers are less affected by sub-optimal pest control strategies and unspecific quarantine restrictions (new knowledge, applications or services are created + uptake by relevant stakeholders)

Pathways of change

According to the above mentioned specific objectives, an intervention strategy will be developed, based on the following pathways of change (under the sphere of interest):

- the local universities and researchers increase their expertise on modelling of pest dispersal, apply this knowledge to a range of tephritid pests, provide relevant information to design more effective pest control strategies
- the local governments adopt specific quarantine measures for *C. rosa* and *C. quilicii*
- farmers and growers improve pest control measures for *C. rosa* and *C. quilicii* and increase production

The **Phases of Change** (under the sphere of control) envisaged by DISPEST and associated to the domain of change 1 (the local university's agricultural departments become more research active, stimulating more efficient pest control strategies in the agricultural sector) rely on the local Universities that will:

- properly characterise the patterns of distribution of *C. rosa* and *C. quilicii*, their host range and population structure.
- model patterns of connectivity among populations of the two species taking into account intrinsic landscape barriers.
- provide relevant information for the development of specific pest control strategies.

While the phases of change associated to the domain of change 2 (farmers and growers are less affected by sub-optimal pest control strategies and unspecific quarantine restrictions) rely on

- the local Universities that will indicate areas suitable as Pest Free Areas (PFAs) and Areas of Low Pest Prevalence (ALPP) and that will train officers from the National Plant Protection Organisation (NPPOs) in the early detection and monitoring of tephritid pests (with emphasis on *C. rosa* and *C. quilicii*).
- the local governments that will be more efficient in tephritid early detection, and will adopt specific quarantine restrictions for *Ceratitis rosa* and *Ceratitis quilicii*.

The main **assumptions** related to the domain of change 1 rely on the recruitment of suitable and productive candidates for a PhD and MSc and an on the research generating the predicted results (different host range and distribution of *C. rosa* and *C. quilicii*). While assumptions for domain of change 2 include sufficient interest and response from NPPOs, from Government as well as from farmers and growers. Based on these assumptions, a risk management analysis is provided in Annex II (SO4 – DISPEST).
The logical framework in Annex I will allow delivering the five intermediate results (R1-R5) described in the following section.

d) Expected results

R1: Strengthening scientific research capacity

Relevant information for the development of optimal pest management strategies is produced based on landscape modelling and integrating data on ecology, distribution and population genetics of *C. rosa* / *C. quilicii* as well as information on intrinsic landscape barriers. A PhD and a MSc are trained in aspects related to ecological modelling of agricultural pests.

R2: Strengthening physical and virtual diffusion of scientific research results to the larger scientific community
Advanced training on morphological and molecular identification of African tephritid pests is organized. Research results are published in international peer reviewed journals and presented at international conferences. Existing websites and fact sheets on fruit fly pest distribution and identification are updated and improved.

R3: Raising awareness towards the general public
Existing educational tools including simplified fact sheets and digital identification tools (and including an android mobile app and multimedia identification key) are updated and improved and distributed to the farming communities ("farmer info days").

R4: Support to good governance, based on the scientific results
Policy briefs on the current distribution and dispersal potential of *C. rosa* / *C. quilicii* and information on areas suitable as PFAs and Areas of Low Pest Prevalence (ALPP) are provided.

R5: Development of synergies and complementary activities among partners through multi-partner governance and coordination
Co-ordination and follow-up meetings with partners involved in fruit fly pest management in Africa are organized.

e) ***Methodology***

R1: Strengthening scientific research capacity

R1.1. generate predictions of the most likely dispersal pathways by modeling existing and newly collected trapping, fruit rearing and population genomic data with estimates of landscape connectivity as inferred from the available climatic (e.g. Worldclim), topographical (e.g. http://due.esrin.esa.int/pa) and host distribution data (e.g. http://projects.bebif.be/fruitfly) databases (Y4). The sampling and rearing campaign (Y1-Y3) will rely on the sampling of 8 to 14 sites in the Southern part of South Africa (coordinated by SU), of 8 to 14 sites in the Northern part of South Africa (coordinated by CRI) and on 5 to 9 sites in southern Mozambique (coordinated by EMU).

R1.2. generate landscape connectivity maps (or inversely, landscape friction maps, Y3-Y4) for the different countries involved by considering key climate and landscape characteristics associated with the dispersal, genetic structure, feeding ecology, and overall distribution of the two target species. Human-mediated effects will be incorporated into the model by considering additional parameters such as the location of major transportation networks, human population density, and common trade routes.

R1.3. infer appropriate management units and provide information on spatial prioritization making use of intrinsic landscape barriers (Y3-4).

R1.4 indicate areas suitable as Pest Free Areas (PFAs) and Areas of Low Pest Prevalence (ALPP) (Y3-4) according to the international standards for phytosanitary measures provided by the Food and Agriculture Organisation of the United Nations (FAO).

R1.5. Supporting 1 PhD student (Y2-4) and 1 MSc (Y2-3) who will collect and analyse data with respect to the above mentioned topics. Substantial training on collection and analysis of collection and analysis of genomic data will be provided at RMCA for the PhD student and the local coordinator (Y2- Y4).

R2: Strengthening physical and virtual diffusion of scientific research results to the larger scientific community

R.2.1. Publication of research results, to disseminate the results to the larger scientific community (Y2-4).

R2.2. Participation at the 4th International TEAM Symposium (France, 2020), and to the 11th International Symposium on Fruit Flies of Economic Importance (Australia, 2022).

R2.3. Enhancement of existing websites on fruit fly pests (e.g. http://projects.bebif.be/fruitfly, http://fruitflykeys.africamuseum.be/) with updated distribution maps and fact sheets for *C. rosa* and *C. quilicii* (Y1-4).

R2.4. Training (five persons) on "Advanced tools for the monitoring and identification of African fruit fly pests". The training will consist of two phases: (a) RMCA staff and international experts will train instructors form the local Institutions (Y2), (b) instructors form the local Institutions, coordinated by RMCA staff will train NPPO officers.

R3: Awareness raising towards the general public

R3.1. Improvement of the currently under-development tools (android app) for the identification of common fruit fly pests, including *C. rosa* and *C. quilicii* (Y3-4).

R3.2. Development of simplified fact sheets for the identification of common fruit fly pests, including *C. rosa* and *C. quilicii,* addressed to the farming communities (Y3-4).

R4: Support to good governance, based on the scientific results

R.4.1. Development of policy brief on dispersion routes and possible intervention and control strategies for *C. rosa* and *C. quilicii* to be distributed to policy makers and other stakeholders, with emphasis on potential establishment of Pest Free Areas and Areas of Low Pest Prevalence (Y4).

R5: Development of synergies and complementary activities among partners through multi-partner governance and coordination

R.5.1. Coordination and follow-up meetings with the main role players involved in fruit fly pest management in Africa, such as the South African and Mozambican Ministries of Agriculture, grower associations and farmers, are organized (Y2, Y4)

f) *Developmental relevance of DISPEST*

DISPEST focusses on the needs and priorities of the partner countries, and will tackle national priorities with respect to poverty reduction and policies for Higher Education.

The activities described above will contribute to the improvement and sustainability of agricultural activities of South Africa and Mozambique, two African countries where small- and large-scale horticulture has major relevance in terms of social and environmental impact.

DISPEST will allow for a more informed and integrated management strategy, including subsistence, small scale and commercial production, which is limited by phytosanitary importance of *C. rosa* and *C. quilicii*. Fruit fly management in South Africa is mainly focused on other tephritid species (such as *C. capitata*), involving the use of protein baits and Sterile Insect Technique (SIT) in specific areas on an area-wide basis. However, limited knowledge of *C rosa* and *C quilicii* in terms of host utilization and distribution impact on management decisions. As SIT is not available for the latter two fly species, a targeted management approach is becoming more important, so that these flies do not take over where *C. capitata* may become less abundant.

DISPEST aims at building regional expertise in centres of excellence and to contribute to the South-South knowledge transfer.

g) *Long term impact of DISPEST*

Impact on crop production and food security:
DISPEST will provide the first fundamental data on the distribution and ecology of *C. quilicii* and will substantially update the knowledge of the distribution of *C. rosa* in South Africa and Mozambique. The deeper knowledge of host range and dispersion routes of these frugivorous pests will promote a more efficient and sustainable agricultural development, with more efficient monitoring (with emphasis on early detection) and targeted pest management plans.

Impact on local partners:
DISPEST will further strengthen the expertise and knowledge of the partners in this field and their recognition as regional centres of excellence in the field of ecology and management of agricultural pests.

h) Sustainability of DISPEST

Challenges for sustainability after DGD funding

The local partners can definitely implement independent research as shown by their scientific production on ecology, taxonomy and pest management of tephritid fruit flies. DISPEST will further strengthen the existing expertise and will promote North-South knowledge transfer on the most recent and advanced genomic tools used in fruit fly research. This will make the local partners even more competitive in developing their future research lines and research and in attracting national and international funds.

Strategy to tackle those challenges

The research institutions involved (SU, CRI, EMU) will actively search and apply for alternative funding during the second half of DISPEST. This will guarantee continuity in the collaborative research already initiated by this and previous projects.

i) Key stakeholders

Southern stakeholders

- **Local universities and researchers**
  Interest & influence: *critical*

Local universities will have a major role in research development and coordination further consolidating their long-standing collaboration with RMCA. Particular attention will be given to the training of young African students (PhD, MSc, emphasis on female candidates) and to their training (that will include periodical visits to RMCA and participation to congresses). RMCA personnel will train instructors from the local universities (North-South knowledge transfer) so that they will actively contribute to the first advanced training course on morphological and molecular identification of African tephritid pests (South-South knowledge transfer).

- **Local governmental Institutions**
  Interest & influence: *critical to high*

The local governmental Institutions will be briefed on invasion risks and establishment of Pest Free Areas (PFAs) and Areas of Low Pest Prevalence (ALPP). NPPO, officers will be trained, (emphasis on female candidates) on early detection and monitoring of tephritid pests (including *C. quilicii* and *C. rosa*)

- **Farmers and growers (including Mozambican and South African Growers Associations**)
  Interest & influence: *high to moderate*

Farmers and growers will be involved (e.g. "farmer info days" organised by SU) and the educational tools developed and optimised (simplified fact sheets, android app, websites) will be used to raise awareness on the importance of early detection and monitoring of tephritid pests.

Northern stakeholders

- **IAEA (International Atomic Energy Agency**)
  Interest & influence: *medium*

IAEA has regional projects in sub-Saharan Africa (e.g. RAF5074 "Enhancing Capacity for Detection, Surveillance and Suppression of Exotic and Established Fruit Fly Species through Integration of Sterile Insect Technique with Other Suppression Methods" (https://www.iaea.org/projects/tc/raf5074)

D. FISHBASE AFRICA

Fishbase for Africa: data dissemination, capacity building & fisheries

Expected outcome 4D: *Up-to-date scientific information about African freshwater and brackish water fish is freely available and ichtyological research capacity is strengthened , mainly for the benefit of developing countries, in order to achieve a correct identification of fishes and provide tools pertinent for studies on fisheries, aquaculture and conservation.*

Within the strategic objective 4 FishBase Africa will seek the following results:
R1: Strengthening scientific research capacity
R2: Strengthening physical and virtual diffusion of scientific research results to the larger scientific community
R4: Support to good governance, based on the scientific results
R5: Development of synergies and complementary activities among partners through multi-partner governance and coordination
For further information, see SO 1, FishBase Africa's main strategic objective.

2. Synergies and complementarities

A. ATRAP

- **With other Belgian actors**

The Protos program coordinator of Uganda and Congo has been contacted to enquire about their interest to be involved as a stakeholder. Hannelore Martens confirmed her interest in the snail and parasite distribution maps (risk maps) of southwestern Uganda. She is also responsible for the Joint Strategic Framework of all Belgian actors in Uganda, and can provide other interesting contacts, including other NGO's and local governments. RMCA is invited to make use of the PROTOS existing 'communities-led total sanitations' networks in case the activities take place in the same area (northern part of Lake George). Another important Belgian development actor is ENABEL, with expertise both in health and education and Be-cause Health (Belgian platform for International Health). ENABEL will be invited for the kick-off meeting.
There are also synergies and collaboration within RMCA, namely the HARISSA activities partly executed in partnership with MUST in Uganda. In HARISSA, a similar network of citizen scientists will be created to report natural hazards like landslides. The meetings in Uganda will be synchronized in order to streamline the trainings of citizen scientists, and hire a joint researcher to study the impact of the citizen science approach.

- **With other actors**

See stakeholder analysis above. In addition to that, targeting snail intermediate hosts of schistosome cercariae augments the MDA efforts by the Vector Control Unit in Uganda as well as the national program for the control of NTDs in Congo in eliminating schistosomiasis This form of concerted effort will potentially yield better results giving hope to vulnerable communities.
The VLIR_UOS SI project of the citizen science approach is already rolled out in the Rwenzori region that neighbors the proposed study area of Ntoroko District, Kazinga and Kyambura river system together with the Bunyaruguru craters. Lastly, the citizen's science approach fits well in the MUST vision "To provide quality and relevant education at national and international level with particular emphasis on Science and Technology and its application to community development".
The unit of vector control of the national program for the control of vector-borne diseases in Congo expressed their interest to use the data generated in ATRAP and partake in the snail surveys. The same is true for entomological services of INRB and the one of the department of tropical medicine at UNIKIN, which are currently short on staff and expertise in medical malacology.

B. AGROVEG

- **With other Belgian actors**

In the Common Strategic Framework (CSF) of Belgian Development Cooperation for Tanzania, one of the joint strategic goals is support to agricultural development (JSG1). The promotion of agroecology is listed specifically (JSG1E). In the CSF for Mozambique, agriculture is a common goal (CS1) with the development of small-scale agricultural activities and with respect for the environment is one the approaches listed (CS1C/CS1E). Agroecological practices as implemented in AGROVEG fulfil these requirements. NGO Rikolto (listed as being active in agroecology in Tanzania) has been contacted and their East African branch has expressed interest in collaboration on pest management for vegetables within the framework of their Arusha Safe Food Initiative.
CEBioS of the Royal Belgian Institute of Natural Sciences is active in the development of policy briefs for different aspects related to development cooperation and has expressed interest in jointly developing a policy brief on agroecological practices.

- **With other actors**

CIRAD La Réunion is the only institution who has already investigated the agroecological approach in the cucurbit production (through the GAMOUR project 2009-2011). Although the isolated conditions on the island, with limited FF diversity, is different from continental Africa, this project has demonstrated the possible applications of particular methodologies. These will be used as a starting point for AGROVEG.
EMU, together with RMCA and a number of South African and Mozambican partners and stakeholders, has developed a project proposal for the STDF (Standards and Trade Development Facility) dealing with amongst other recognition and establishment of Pest Free Areas in Mozambique and South Africa for *Zeugodacus cucurbitae*. If approved, this project will provide complementary data on distribution patterns for this alien pest in the country and allow synergetic activities with the other partners of the STDF project.
AGROVEG will complement previous projects at SUA on Conservation Agriculture under program on Enhancing Pro-poor Innovation in Natural Resources and Agricultural Value Chains (EPINAV) supported by Norwegian Agency for Development (NORAD); In vitro propagation of banana under Programme for Agricultural and Natural Resources Transformation for Improved Livelihood (PANTIL) supported by NORAD; Climate Change Impacts Adaptation and Mitigation (CCIAM) supported by NORAD; Project on Enhancement of fruits preservation using nano technology (supported by IDRC); Building Stronger Universities Phase II (BSU), sub theme of Agro ecology (funded by Danish International Development Agency, DANIDA), Agro ecology research and advocacy (supported by SwissAid); and the Southern Agricultural Growth Corridor of Tanzania (SAGCOT).
Contacts have been made with the International Centre for Insect Physiology and Ecology (ICIPE, Nairobi, Kenya) who has been active in the field of FF research for about two decades. Negotiations are running with the EU to develop a new research program which may include agroecological aspects on FF. If this materializes, complementary activities are envisaged.

C. DISPEST

- **With other Belgian actors**

CEBioS of the Royal Belgian Institute of Natural Sciences (RBINS) is active in the development of policy briefs for different aspects related to development cooperation and has expressed interest in participating to the development of a policy brief on the current distribution and dispersal potential of *C. rosa* / *C. quilicii* (see R4: Support to good governance, based on the scientific results).
VLIR-UOS, APOPO, Rode Kruis, Oxfam Solidarité, Viva Africa and DISOP for Mozambique and Trias and BOS+ for South Africa are contacted to verify possible synergies with respect to

the dissemination of scientific results and identification of the target pests in rural communities (see R3: Raising awareness towards the general public).

- **With other actors**

EMU, together with RMCA and a number of South African and Mozambican partners and stakeholders, has developed a project proposal for the STDF dealing with recognition and establishment of Pest Free Areas in Mozambique and South Africa for *Zeugodacus cucurbitae*. If approved, this project will provide complementary data on distribution patterns for two additional agricultural pests (*C. rosa and C. quilicii*) in the country and allow synergetic activities with the other partners of the STDF project.

SO5. Natural resources have an improved contribution to sustainable development

Photo 5. *Fieldwork in the Biosphere Reserve of Yangambi (PilotMAB)* – © RMCA

1. Contributions to strategic objective 5

A. GEORES4DEV

Les géoressources : contribution majeure au développement durable de l'Afrique centrale

Expected outcome 5A: Local expertise and academic research on the geology of mineral geo-resources and their social impact in Central Africa is strengthened in the framework of an integrated and sustainable management.

Countries where the activities take place: Burundi, DRC, Rwanda, Rep. Congo

Summary
Par son travail de formation et de construction de capacités scientifiques, académiques et techniques ("capacity building") sur la thématique de la Géologie sociétale et les géoressources, avec en total 5 partenaires académiques Sud dans 3 régions-sujets (Kongo Central- Sud Rep. Congo, Katanga et Kivu-Rwanda-Burundi), GeoRes4Dev veut palier aux lacunes en information de base et en connaissances actualisées de ces pays producteurs de géoressources. Soutenir leurs établissements d'enseignement supérieur en renforçant leurs capacités en matière de formation, de recherche et de services à la société, est donc un enjeu fondamental. Les effets se feront sentir sur le long terme par l'intégration progressive de ces nouvelles connaissances par les acteurs locaux responsables de la bonne gestion des géoressources. Les informations largement diffusées seront pérennisées et pourront servir de base aux travaux futurs.

Keywords: géologie des géoressources, Afrique centrale, géologie sociétale, formations universitaires, bases de géodonnées et SIG

DAC sector code & policy markers: 11420, 32220

Partnerships:

- Université du Burundi (UB), Bujumbura, **Burundi**
  Faculté des Sciences, Département des Sciences de la Terre
- Université de Kinshasa (UNIKIN), **DRC**
  Faculté des Sciences, Département des Sciences de la Terre
- Université de Lubumbashi (UNILU), **DRC**
  Faculté des Sciences Sociales, Politiques et Administratives
- Université Officielle de Bukavu (UOB), **DRC**
  Faculté des Sciences et Sciences Appliquées, Département de Géologie
- University of Rwanda (UR), Kigali, **Rwanda**
  College of Sciences and Technology (CST), School of Mining and Geology (SoMG)
- Centre de recherches géologiques et minières (CRGM), Kinshasa, **DRC**
- Université Marien Ngouabi (UMNG), Brazzaville, **Republic of Congo**
  Faculté des Sciences et Techniques

RMCA promoters: Pascale LAHOGUE, Max FERNANDEZ (Earth sciences)

a) *General context*

Development problem that GeoRes4Dev wants to tackle and its sectoral context

Le développement extraordinaire des sociétés modernes a été avant tout – et reste largement - basé sur l'exploitation de géoressources (ressources minérales, hydriques et énergétiques)**.** Elles sont à la base du développement accéléré des villes et particulièrement des mégapoles (matériaux de construction, eau, matériaux de base pour l'industrie, substances énergétiques). Globalement, les géoressources interviennent aussi dans le développement des nouvelles technologies (terres rares, cobalt, vanadium, germanium...). Leur demande mondiale est en augmentation constante alors même que la disponibilité des géoressources facilement extractibles et/ou extractibles à faible coût environnemental, diminue.

L'abondance des géoressources varie considérablement dans l'écorce terrestre, et des mécanismes géologiques les plus divers ont contribué à leur accumulation dans des gisements plus ou moins concentrés. La connaissance scientifique de l'histoire géologique de la Terre et des processus de formation des géoressources qui y sont associées, la connaissance des écosystèmes et de la biodiversité, et l'interaction de l'homme avec ces systèmes sont importants pour nous aider à comprendre comment gérer notre Planète et lui assurer un avenir durable. Curieusement, à la différence de la biodiversité et du climat, qui font l'objet au niveau planétaire de conventions spécifiques, la question des géoressources est rarement considérée au niveau global parmi les thèmes relevant des problématiques du développement durable. **Cependant, compte tenu des connaissances scientifiques actuelles en sciences de la Terre, leur gestion durable est concevable tant au niveau local que global.**

Les géologues - géoscientifiques - peuvent amener leur part de réponses à ce nouveau modèle, plus spécialement par le biais de la nouvelle discipline de la **Géologie Sociétale**. Elle part du principe que les géoressources doivent ou devraient faire l'objet d'une exploitation de plus en plus compatible avec le concept de développement durable. Cela suppose que l'exploitation de ces ressources doit être analysée et comprise également dans leur contexte économique et social, et qu'une organisation appropriée doit se mette en place impliquant l'ensemble des parties prenantes tant au niveau local que global.

Dans ce cadre, la recherche académique en géologie et en géoressources ne devrait plus seulement viser la mise au point d'approches toujours plus pointues et performantes d'études géologiques et de reconnaissance, d'estimation, de traitement et de gestion des gisements. Elle doit viser également - de plus en plus - la prise en compte des dimensions environnementales, économiques, sociales et de santé publique des anciens et futurs gisements et zones d'exploitations.

Il est impératif dans l'optique de bonne gouvernance des géoressources, qu'un pays dispose de moyens publics de recherche académique et de gestion de l'information, ainsi que d'un cadre administratif garantissant la collecte et la gestion des informations stratégiques sur le sous-sol, même lorsque celles-ci sont acquises par des entreprises privées. **Il lui faut également une capacité d'analyse stratégique et de prospective globale** qui trop souvent est concentrée dans les mains des opérateurs privés et dans les pays industrialisés "utilisateurs" des géoressources.

Cette **"intelligence minérale"** d'un pays doit être fondée sur une approche combinant :

- l'acquisition de (nouvelles) données géologiques, gîtologiques et métallogéniques ;
- l'acquisition de données économiques, sociales et environnementales relatives aux ressources minérales et aux risques engendrés par leur exploitation et utilisation;
- la veille active sur l'évolution des politiques sectorielles, de l'organisation institutionnelle et sur le jeu des acteurs publics et privés engagés dans le secteur ;
- le traitement des informations en résultant, sous forme d'études, de synthèses, de bases de données et de Systèmes d'Informations Géographiques (SIG) diffusés via différents média et supports (Internet, papier, CD-ROM, …).
- une politique de communication et de vulgarisation visant les parties prenantes à la conception des politiques publiques.

Aujourd'hui trop souvent, les pays (africains) "producteurs de géoressources" se trouvent confrontés à des handicaps majeurs de savoir ("**knowledge gap**"), vis-à-vis des autres acteurs du secteur que sont les groupes miniers privés et les industries des pays industrialisés.

- Ils ne disposent pas / plus de l'information de base qui leur est nécessaire concernant leur sous-sol et leurs propres ressources. C'est pourtant là une question stratégique pour leur développement. On a assisté les dernières décades à des mutations profondes, de sorte

que ces capacités autrefois gérées dans la sphère publique, tendent à se concentrer exclusivement dans les groupes privés et dans les pays industrialisés.

- Ils ne disposent pas ou plus assez de la maîtrise des connaissances en sciences de la Terre actuelles liées à leurs ressources, ni ne possèdent assez de savoir-faire en matière "d'intelligence minérale".

Pallier à ces carences en matière de ressources humaines académiques spécialisées implique un important effort de formation et de promotion des capacités scientifiques, académiques et techniques ("*capacity building*"). **Soutenir par une approche intégrée ("*institutional cooperation*") le potentiel considérable des établissements d'enseignement supérieur et des instituts de recherche africains en renforçant leurs capacités en matière de formation, de recherche et de services à la société, est donc une priorité fondamentale pour la gestion durable des géoressources.** Ceci constitue un maillon déterminant de la chaîne des compétences et, par conséquent, de celle du développement, un maillon indispensable à l'implémentation de politiques publiques.

C'est sur le constat développé ci-dessus que le service Géodynamique et Ressources Minérales (GRM) du département des Sciences de la Terre du MRAC fonde sa mission de coopération au développement, avec l'objectif d'**apporter une contribution effective à la consolidation de la société africaine et au développement durable. Dans le contexte de la géologie sociétale et des géoressources**, le service GRM propose de développer pour le programme pluriannuel 2019-2028 l'ensemble d'activités "Georesources for Development (GeoRes4Dev)". Il s'agit d'activités de "*capacity building*" académique, au bénéfice de – et en collaboration avec - des universités et centres de recherches partenaires africains, sur la thématique du contexte géologique et sociétal des géoressources minérales et de leur contribution au développement durable.

L'objectif spécifique de GeoRes4Dev est de contribuer à améliorer l'expertise académique locale sur la géologie des ressources minérales et leur impact sociétal dans le cadre d'une gestion intégrée en impliquant toutes les parties prenantes (populations locales, experts, acteurs économiques, responsables politiques).

L'objectif plus global de GeoRes4Dev est que la demande globale en ressources minérales bénéficie davantage aux acteurs locaux dans les pays-cibles de l'Afrique centrale.

Capacity constraints and needs of the partner institutions

Il y a cette année à l'Université du Rwanda (UR) un seul Professeur détenteur d'un doctorat pour encadrer une cinquantaine d'étudiants finalistes, deux pour une quarantaine de finalistes à l'Université Officielle de Bukavu (UOB), quatre pour une trentaine de finalistes à l'Université du Burundi (UB). À Kinshasa, l'effectif professoral est plus important mais avec une moyenne d'âge très élevée et très peu de Docteurs en Géologie susceptibles de les remplacer et le constat est similaire dans les instituts de recherches et autres Universités (Lubumbashi,...). Mais outre cela, aucune université concernée par le projet n'a développé de formation en géologie sociétale, concept innovant aussi pour la Belgique mais particulièrement important pour l'Afrique centrale.

GeoRes4Dev a pour but de renforcer les capacités académiques de ces institutions universitaires en permettant à un certain nombre de scientifiques d'acquérir les diplômes nécessaires pour remplir ces postes au sein des universités ou des instituts de recherche. Leur formation se déroulant dans les Universités locales, cela permettra aussi aux **Universités de pouvoir exercer de manière efficace une autre de leur triple mission, celle du service à la société, en intégrant ses activités dans un dialogue sur la responsabilité sociale et environnementale des exploitations en carrière ou en mine et sur la responsabilité de prendre en compte l'éventuel impact négatif de leurs activités sur la genèse et le développement des conflits, en vue d'une bonne gouvernance du secteur.** Pour les mines par exemple, elle résulte en effet d'une combinaison de trois actions inter-reliées : au niveau de la mine proprement dite avec les

travaux techniques de production, en aval de la mine avec la gestion des flux de commercialisation, mais aussi en amont de la mine avec des travaux de reconnaissance et de caractérisation des minéralisations et leur contexte, dont dépend la transparence dans l'attribution des licences d'exploration et/ou d'exploitation.

Par une valorisation de l'expertise et des archives du MRAC dans l'accompagnement et l'encadrement des travaux de Master et de Doctorat, avec des missions ponctuelles d'experts du MRAC pour les travaux de terrain, avec des périodes de « mobility exchanges » au MRAC et dans les universités collaboratrices, avec la possibilité d'appui, suivi et échange à distance, GeoRes4Dev contribue à la formation des compétences nécessaires.

Afin de renforcer les établissements ciblés et d'assurer d'une garantie de qualité des observations et de leurs interprétations, des partenariats sont prévus. Dans l'Est, les trois Universités régionales ont convenu d'un partenariat sud-sud qui sera épaulé par le Musée Royal d'Afrique Centrale de Tervuren (MRAC). Ce dernier est sollicité pour son expertise sur la géologie de la région et pour assurer des codirections de thèses de recherche en géologie effectuées à l'École Doctorale de l'Université du Burundi. Ceci s'intègre parfaitement dans la volonté politique de la Belgique de « réorienter des budgets de sa coopération aussi vers des acteurs non politiques et non gouvernementaux ».
Dans l'Ouest, le projet permettra de développer avec l'UNIKIN les collaborations entamées entre le CRGM et l'Université Marien Ngouabi avec l'aide du MRAC et les mêmes objectifs que dans l'Est.

Les campagnes de terrains indispensables à toute étude géologique à réaliser permettront d'acquérir les connaissances aujourd'hui manquantes pour mettre à jour les cartes géologiques nationales et actualiser la vision de la géologie régionale et des ressources minérales et risques associés tout en tenant compte de leur impact sociétal et environnemental. Cette activité indispensable est fortement réduite au niveau des ministères en charge de la géologie qui se concentrent essentiellement sur les statistiques de production et les flux de commercialisations des minerais. Les missions des scientifiques du MRAC seront donc importantes car indispensables pour l'acquisition des données et échantillons et pour la transmission des méthodes d'observation, et d'interprétations sur le terrain, sources d'information indispensables à toute étude géologique. Ils profiteront aussi de leur passage dans les instituts partenaires pour diffuser leurs connaissances vers un nombre le plus large possible de scientifiques lors de séminaires et conférences.
Les séjours des boursiers sont nécessaires pour leur donner l'accès à aux collections MRAC et moyens d'analyses du MRAC et de ses partenaires Nord ainsi que pour travailler, échanger avec leurs promoteurs belges sur les résultats acquis l'année en cours et ce dans les meilleurs conditions possibles. Les services (géologiques) nationaux en charge de la géologie et des géoressources s'orientent de plus en plus vers la « gestion des flux de commercialisation des minerais » et ce sont les universités qui s'occupent des aspects de la recherche. La collaboration entre ces universités nationales et le MRAC et la reconnaissance des chercheurs du MRAC parmi des membres de comités de thèses réalisées dans le cadre d'études de 3e cycle de ces universités, permettent de doter cette recherche universitaire d'un caractère régional, qui sera consolidé par les réunions régionales de synthèse à mi-parcours et de validation à la fin du projet prévues par GeoRes4Dev. La connaissance régionale de l'équipe GRM du MRAC sera notamment portée par des scientifiques qui ont contribué à l'acquisition des premières données de terrain au cours de projets ex-AGCD avec le soutien d'anciens professeurs en géologie de ces universités.
Vu la situation économique actuelle des pays partenaires, l'accès aux DEA et Doctorat est financièrement difficilement soutenable pour les jeunes scientifiques Cela entraîne un nombre réduit de jeunes diplômés qualifiés pour renouveler le cadre professoral des Universités et les cadres des Instituts de recherche souvent encore vieillissant car trop peu renouvelés. Pour les

partenaires locaux, ce projet permet à la fois de promouvoir les formations doctorales et en DEA par des inscriptions supplémentaires et dans un second temps de disposer de jeunes diplômés pouvant être intégrés à un échelon plus élevé au sein de leur institution. Le fait de réaliser leur travaux en partenariat avec le MRAC leur permet en outre d'acquérir des données et des concepts scientifiques dont ils ne peuvent disposer localement et qui profiteront aux institutions partenaires locales.
GeoRes4Dev fournira le soutien nécessaire à la formation d'un nombre significatif d'enseignants-chercheurs au niveau DEA, Master ou Doctorat dans le domaine des sciences de la Terre (y compris sa dimension sociétale) liées aux géoressources et géomatériaux. Il contribuera par la même occasion à une amélioration de la connaissance scientifique dans ces domaines.

b) *Background*

Partnership/ownership

GeoRes4Dev est le fruit de discussions et contacts avec des instituts et organisations locales avec lesquelles le Service GRM entretient depuis plusieurs années de contacts et/ou développe des activités de coopération et de recherche.
Dans le cadre des MoU signés entre le Musée Royal de l'Afrique Centrale et l'Université Officielle de Bukavu, l'Université du Burundi et l'Université du Rwanda, les partenaires se sont entendu sur une action spécifique «Région des Grands Lacs – Couloir de Minéralisation, Corridor de Développement Régional (COMICODE)»
Au Kongo central (ex Bas Congo) et la région du Pool (Kinshasa, Brazzaville) les partenaires de la RDC sont intéressés à s'inscrire dans la thématique géoressources – géotechnique et géologie sociétale et veulent y développer à terme un "pool" de connaissances ayant trait spécifiquement aux besoins en géoressources des (grandes) villes. L'Université Marien Ngouabi de Brazzaville, déjà partenaire du CRGM, complétera ce "pool" en offrant la possibilité de compléter les observations de l'autre côté du fleuve Congo.
Au Katanga le service GRM s'est associé avec l'Université de Lubumbashi et le Centre Carter (Lubumbashi) pour couvrir plus spécifiquement l'impact sur la société humaine des opérations minières.

Previous experiences between the partners

GeoRes4Dev est un nouveau concept qui cible essentiellement des formations diplômantes et la recherche académique avec 6 universités partenaires. Le service GRM collabore – ou a collaboré - cependant depuis plusieurs années avec ces partenaires dans le cadre d'activités de recherche et/ou de coopération.

- UNIKIN / CRGM: encadrement de thèses DEA et PhD, et de travaux de recherches scientifiques, financés par 2 programmes pluriannuels MRAC-DGD (2008-2018): Projet S1_RDC_CRGM (Renforcement de la capacité de recherche et de service géologique du Centre de Recherches Géologiques et Minières en RDC
- UNILU: encadrement de thèses MSc, DEA et PhD, financé par 2 programmes pluriannuels MRAC-DGD (2008-2018): Projet S1_RDC_GEODYN : Développement des capacités en géodynamique à l'UNILU, RDC
- UOBukavu: Projets S1_RGL-GEORISK (Développement des capacités en observation et étude des géorisques dans la Région des Grands Lacs) et S1_RGL-GEOKIVU (Valorisation et exploitation des géo-données au Kivu), coopération technique financée par le programme pluriannuel MRAC-DGD (2014-2018). BELSPO Projet RESIST (Remote Sensing and In Situ detection and Tracking of Geohazards).
- Université du Burundi: projet CTB 2016 (Enabel), en collaboration avec le Service Géologique du Burundi, dont la principale recommandation a été la nécessité de collaborer avec l'université pour un travail sur du long terme de recherche géologique de

mise à jour de la carte géologique du pays, en produisant des cartes numériques au 50.000ème à la fin du projet

- University of Rwanda: projet Enabel 2018 (en collaboration avec le Rwanda Mines Board), dont les conclusions préliminaires recommandent comme au Burundi une mise à jour de la carte géologique du pays en s'appuyant sur le format numérique des cartes au 50.000ème disponibles au MRAC
- Université Marien Ngouabi travaux de recherches scientifiques, financés sur le programme pluriannuel MRAC-DGD (2014-2018) (CRGM).

Les sites en ligne RDCMINING et GeoKIVU, conçus et financés sur le Knowledge centre des programmes pluriannuels MRAC-DGD (2008-2018), seront récupérés en GeoRes4Dev et développés pour devenir le noyau d'un nouveau système de documentation et d'informations en ligne sur les géoressources en Afrique centrale.

c) *Theory of Change*

L'objectif global de GeoRes4Dev est que la demande globale en ressources minérales bénéficie davantage aux acteurs locaux dans les pays-cibles de l'Afrique centrale dans des conditions d'exploitation respectueuses de l'environnement et des populations locales.

L'objectif spécifique de GeoRes4Dev est de contribuer à améliorer l'expertise et la recherche académique locale sur la géologie des géoressources minérales et leur impact sociétal, dans le cadre d'une gestion intégrée et de développement durable.

Soutenir par une approche intégrée le potentiel considérable des établissements africains d'enseignement supérieur et de recherche en renforçant leurs capacités en matière de formation, de recherche et de services à la société en impliquant toutes les parties prenantes (populations locales, experts, acteurs économiques, responsables politiques), est une priorité fondamentale pour la gestion durable des géoressources. Ceci constitue un maillon déterminant de la chaîne des compétences requises pour le développement durable de tout pays minier et, par conséquent, est un maillon indispensable à l'implémentation de politiques publiques.

Pallier aux carences existantes en matière de ressources humaines académiques spécialisées en Afrique dans le domaine des géoressources, de leur contexte géologique et sociétal, implique cependant un important effort de formation et de promotion des capacités scientifiques, académiques et techniques ("*capacity building*"). C'est sur ce constat global que le service Géodynamique et ressources minérales (GRM) du MRAC propose pour le programme pluriannuel 2019-2023, "Georesources for Development (GeoRes4Dev)". Les chercheurs du service GRM ont acquis ces dernières années de nouvelles données et connaissances qui peuvent directement être exploitées, partagées et complétées par de nouveaux travaux de recherches d'étudiants et/ou de chercheurs des partenaires locaux. Dans les disciplines où l'expertise ou des données du service GRM seraient lacunaires, il s'associera à des partenaires académiques belges, africains et internationaux avec lesquels il entretient déjà des contacts.

Cependant, la problématique et le rôle des géoressources minérales dans l'économie et la géopolitique internationale est un domaine complexe dépendant des contextes géologique, économique et sociétal dans lesquels se trouve une ressource particulière. Dès lors, 3 sujets qui correspondent à des problèmes et besoins régionaux distincts en Afrique centrale ont été choisis: La région des Grands Lacs (volet COMICODE), la région SW de l'Ex-Katanga (volet Lualaba) et la région entre le Pool et la côte Atlantique (volet Kongo).

La thématique « géologie sociétale » sera un sujet transversal. En effet, l'aspect sociétal des géoressources ne peut plus être considéré comme un aspect local. Pour chacun de ces trois sujets, seront pris en considération leur impact sur la société, la manière dont ils sont gérés dans le contexte social, de santé publique, d'économie politique et de gouvernance.

Un second sujet transversal couvre toute l'informatisation à mettre en œuvre pour la distribution et la publication des résultats et des connaissances acquises sous forme de « centre de documentation en ligne ».

1. Le volet COMICODE.

Dans le cadre des MoU signés entre le MRAC et l'Université Officielle de Bukavu, l'Université du Burundi et l'Université du Rwanda, les partenaires se sont entendus sur une action spécifique «Région des Grands Lacs – Couloir de Minéralisation, Corridor de Développement Régional».

Actions à entreprendre :

- Mener des activités de transfert de connaissances et de recherche académique géologique et sociétale sur les facteurs contrôlant le contexte de l'exploitation des minéralisations des 3T (étain, tantale, tungstène) et de l'or, tant à l'échelle régionale que locale au niveau des sites miniers.
- Une diffusion via site(s) internet des connaissances académiques accrues sur les géoressources et les impacts socio-environnementaux de leur exploitation comme la déforestation, les glissements de terrain, la dégradation des sols et leurs conséquences sur la diminution des récoltes.

Objectifs :

- Un outil d'aide à la décision pour les autorités tant régionales, nationales que locales.

Impact :

L'intervention envisagée principalement sur le développement du facteur humain par la formation de troisième cycle au niveau Master et Doctorat et l'encadrement de chercheurs, en amont de l'entrée dans le milieu du travail, aura un impact important bien au-delà des termes du projet. Elle touche ainsi un nombre important de jeunes qui en bénéficieront lors de leurs études universitaires, produisant des lauréats sensibilisés à la géologie sociétale qui pourront être immédiatement opérationnels dans les emplois auxquels ils accèderont, au sein des services géologiques nationaux, des coopératives ou sociétés privées opérant dans le secteur minier.

- Mise à disposition des universités et centres de recherches partenaires d'enseignants et chercheurs au niveau DEA ou doctorat.
- Capacité améliorée des universités et centres de recherches partenaires pour l'enseignement et la recherche sur le contexte géologique et sociétal des géoressources.
- Une meilleure connaissance du contexte géologique et tectonique des zones étudiées qui permettront une meilleure gestion des géoressources et leur prise en compte dans les politiques de développement régional.

2. Le volet LUALABA

Le Katanga est une région idéale pour aborder la thématique-titre de ce projet de collaboration bilatérale entre l'UNILU et le MRAC : « *les ressources naturelles ont une contribution améliorée au développement durable* ». La région est riche en ressources minérales (notamment Cu, Co, U, Mn, Au) et elle a fait l'objet d'une intense exploitation minière depuis plus d'un siècle. Les ressources exploitées ont évolué au cours du temps et les méthodes d'exploitation également. Les terrains de surface de la province sont souvent riches en métaux, soit parce que les gisements sont naturellement à l'affleurement ou proches de la surface, soit parce que l'activité minière a laissé de considérables zones de friches industrielles et de nombreuses pollutions. Le service GRM du MRAC s'est associé avec l'Université de Lubumbashi et le Centre Carter (Lubumbashi) pour couvrir ce volet.

Actions à entreprendre:

Mener des activités de transfert de connaissances et de recherche (transversale) sur l'interaction entre les domaine géologique, métallogénique, pédologique, biologique et de santé publique de cette région.

Objectifs:

Améliorer les connaissances académiques transdisciplinaires sur l'interaction entre la géosphère et la société humaine, contribuant ainsi au développement durable de la province.

Impact:
Mise à disposition des universités et centres de recherches partenaires d'enseignants et chercheurs au niveau DEA ou doctorat.

- Capacité améliorée des universités et centres de recherches partenaires pour l'enseignement et la recherche sur le contexte géologique et sociétal des géoressources.

Une meilleure connaissance du contexte géologique et tectonique des zones étudiées qui permettront une meilleure gestion des géoressources et leur prise en compte dans les politiques de développement régionales.

3. Le volet KONGO

L'ouest de la RDC et de la République du Congo, allant de l'Atlantique au 17ème parallèle Est et entre les latitudes 4 à 7 Sud, recèle de nombreuses ressources industrielles, quelques ressources minérales et des ressources en eau et énergétiques nécessaires tant à la mégapole Kinshasa qu'à des villes plus « petites » mais en plein développement démographique et économique (Boma, Matadi, Kimpese, etc. en RDC mais aussi Brazzaville et autres centres urbains en RC). La connaissance accrue du contexte géologique et des mouvements tectoniques de cette région devra permettre de préciser les zones potentielles de ressources minérales mais aussi les zones à risque suite aux mouvements tectoniques et à la nature même de la roche.

Actions à entreprendre:

- Mener des activités de transfert de connaissances, de recherches géologiques et sociétales et d'études du contexte géologique et géotechnique de cette région.

Objectifs:

- Préciser les zones potentielles de (nouveaux) gisements et/ou d'exploitation des géoressources aptes à une éventuelle exploitation durable.
- Mieux connaitre l'influence de la tectonique (active et historique) et du karst (dissolution de certaines formations lithologiques) sur le soubassement des zones de développement urbain.

Impact:

- Une meilleure connaissance du contexte géologique et tectonique des zones étudiées qui permettront une meilleure gestion des géoressources et leur prise en compte dans les politiques de développement régionales.
- La connaissance approfondie des potentialités en géoressources et aux risques de déploiement d'activité dans des zones définies permettra aux décideurs locaux d'accorder des permis d'exploitation plus judicieusement en tenant compte de leur impact sur la société.
- Pour les instituts de recherche, cette expérience leur permettra d'étendre les connaissances acquises sur d'autres zones.
- Des enseignants et chercheurs au niveau DEA ou doctorat.
- Capacité améliorée des universités et centres de recherches partenaires pour l'enseignement et la recherche sur le contexte géologique et sociétal des géoressources.

d) Expected results

R1 : Capacités de recherche scientifique renforcées

Les capacités scientifiques des partenaires Sud seront améliorées dans leur triple mission de formation, de recherche et de service à la société par les synergies développées entre les universités partenaires de la RDC, du Burundi, du Rwanda et de la RC avec le service GRM, que ce soit lors de séjours de courtes durées en Belgique et en Afrique, de projets conjoints de recherche ou lors de la supervision/codirection de thèses de doctorat, DEA ou de maîtrise.

Les connaissances sur la géologie régionale, les géoressources associées, ainsi que l'impact environnemental et sociétal de leur exploitation seront mieux connus.

Les activités de recherche elles-mêmes visent un double objectif :
(1) Créer et organiser une meilleure compréhension du secteur minier-géoressources régional, national, international, y compris dans ses aspects économiques et politiques ;
(2) Fournir une base scientifique à des revendications d'ordre social (y inclus la gestion de l'environnement, de la santé publique et des risques) et de développement (y compris la contribution du secteur minier à la croissance et au développement durable du pays).

Le volet COMICODE

- R1.1 Une nouvelle cartographie des impacts des activités minières sur l'occupation du sol, – comme p.ex. la déforestation, les effondrements et les glissements de terrain – est établie.
- R1.2 Les capacités des universités partenaires Sud sont renforcées dans leur service à la société, à travers une action commune d'établissement et de partage d'une plate-forme de connaissances actualisées sur la géologie régionale et les couloirs miniers transfrontaliers qui y sont associés;
- R1.3 L'impact des activités minières sur la société est mieux étudié et compris.

Le volet LUALABA

- R1.4 Les développements récents dans la connaissance de la géologie régionale et la métallogénie de la province sont transférés aux partenaires Sud, avec un accent mis sur les formations géologiques moins bien étudiées.
- R1.5 La pédologie est mieux étudiée avec des approches modernes, et spécifiquement les processus de développement des sols et saprolites en climat tropical humide, le développement des dépôts résiduels latéritiques, les aspects pédologiques des minéralisations supergènes, et la formation d'efflorescences salines à métaux en contexte minier.
- R1.6 Les problèmes de santé des populations dus à une exposition importante (surtout celle active dans les mines artisanales) à plusieurs métaux potentiellement toxiques (Co, Mn, U) est cartographiée; le risque d'exposition est évalué.
- R1.7 Les dommages collatéraux des exploitations minières sur l'environnement et la biodiversité sont évalués.
- R1.8 Une unité de recherche interdisciplinaire sur la bonne gouvernance des géoressources est opérationnelle au sein de L'Université de Lubumbashi.

Le volet KONGO

- R1.9 Les développements récents dans la connaissance de la géologie régionale de la province sont transférés aux partenaires Sud, avec un accent mis sur les complexes magmatiques et métamorphiques sources possibles de géoressources, les phénomènes tectoniques et de karst source potentielle d'instabilité du sous-sol; la cartographie au 1/200.000 de la province Kongo central.
- R1.10 Les structures tectoniques des différents secteurs de la région du Kongo Central et région avoisinante du Congo Brazzaville sont mieux connues et les zones potentielles de tectonique active et/ou (sub)récente sont identifiées.
- R1.11 Les phénomènes karstiques avec leurs risques d'effondrements se situant dans les formations calcaires s'étendant au Kongo central (Bas-Congo) et dans leur prolongement au Congo Brazzaville sont mieux connus.

Commun aux 3 volets:

- R1.12 Les étudiants en thèse soutenus dans le cadre de GeoRes4Dev ont acquis de nouvelles connaissances spécialisées. Les thèses PhD, DEA et/ou MSc sont finalisées et les défenses ont eu lieu dans leur université partenaire. Le tout améliore les connaissances scientifiques des partenaires Sud sur les sujets couverts.

- R1.13 Une série de modules de formation et de conférences sur les thématiques couvertes par GeoRes4Dev ont été organisés et dispensés aux universités partenaires
- R1.14 Des résultats nouveaux obtenus grâce aux travaux de terrain et de recherche sont disponibles pour la réalisation de publications conjointes MRAC + partenaires Sud dans des périodiques "peer-review" et sont diffusés auprès de la communauté scientifique.

R2 : Capacités de diffusion physique et virtuelle des résultats des recherches scientifiques renforcées
Au cours des travaux dans le cadre de recherches, de thèses de doctorat ou de maîtrise, codirigées par les experts du MRAC avec des collègues d'autres universités partenaires, les étudiants, assistants et chercheurs des instituts partenaires produiront des documents scientifiques de haute qualité, diffusés sous forme de "peer reviewed papers". Ils organiseront et/ou contribueront à des conférences et réunions scientifiques, et autres rapports pour le grand public.

La diffusion virtuelle des activités de recherche et d'archivage de données est assurée par la récupération des données d'archives ou l'acquisition de nouvelles données enregistrées dans des systèmes numériques. Toutes ces données seront, dans une certaine mesure et avec certaines restrictions, disponibles en ligne via des plates-formes Web accessibles tant aux scientifiques et professionnels qu'au public.

- R2.1 Les nouvelles connaissances acquises sont diffusées sous forme de "peer reviewed papers » dans des journaux scientifiques internationaux, d'articles dans des revues plus locales, contributions à des conférences, thèses et autres rapports pour le grand public.
- R2.2 Les (jeunes) chercheurs des universités partenaires ont appris à produire des documents scientifiques de haute qualité.
- R2.3 Les données d'archives et documentaires exclusivement sous format papier sont numérisées dans des bases de documentation et des systèmes SIG accessibles par intranet (pour les partenaires) et Internet (pour le public).
- R2.4 Toutes les nouvelles données et résultats des études MSc, DEA et PhD sont accessibles par Internet.
- R2.5 Un réseau national de chercheurs et professeurs étudiant le secteur des géoressources sous tous ses aspects est mis en place.
- R2.6 Un centre de documentation et de connaissances (« knowledge centre ») WebGIS sur les ressources naturelles en Afrique centrale est opérationnel en ligne, avec la collaboration d'autres institutions partenaires.

R3: Capacités de sensibilisation et conscientisation de la population et des professionnels renforcées
La population et les autorités seront informées par les institutions partenaires des connaissances géologiques, minières et sociétales acquises. Ceci contribuera à la mise en place d'une gestion transparente et d'une bonne gouvernance en amont (attributions des permis et licences d'exploration et d'exploitation) et à l'exploitation durable des géoressources en aval (collectes des statistiques de production et de commercialisation ainsi que des recettes y associées).

Dans un marché qui a tendance à prospérer dans l'opacité, une publicité sera donnée aux plates-formes numériques de connaissances acquises pour une plus grande visibilité à l'intention des différents acteurs – décideurs locaux, coopératives et entreprises minières, chambres sectorielles-mines des fédérations de commerce et industries – en vue de servir de guide pour une exploitation plus rationnelle et efficiente des ressources régionales.

- R3.1 Les institutions partenaires communiquent au public et aux autorités sur les impacts de changements environnementaux (déforestation, effondrements, glissements de terrain) détectés en rapport avec les activités d'exploitation des ressources.
- R3.2 Les institutions partenaires communiquent au public et aux autorités sur les connaissances académiques géologiques et minières acquises, en vue de leurs applications

pour une gestion transparente et une bonne gouvernance en amont (attributions des permis et licences d'exploration et d'exploitation) et en aval (collectes des statistiques de production et de commercialisation ainsi que des recettes y associées) des opérations minières proprement dites.

- R3.3 Des plates-formes de connaissances ayant une grande visibilité à l'intention des différents acteurs – décideurs locaux, coopératives et entreprises minières, chambres sectorielles-mines des fédérations de commerce et industries – sont en ligne en vue de servir de guide pour une exploitation plus rationnelle et efficiente des ressources régionales.

R4 : La bonne gouvernance renforcée sur base des résultats scientifiques

La bonne gouvernance est améliorée par le partage des connaissances acquises avec des institutions non-scientifiques, gouvernementales et sociétés civiles, ce qui constituera une aide à la prise de décisions en rapport avec l'évaluation d'impacts environnementaux et sociétaux de l'exploitation des géoressources.

La formation des experts en géologie est renforcée par la conceptualisation et la diffusion d'une approche holistique de la géologie, y compris par une ouverture sur la perspective sociétale.

- R4.1 Une aide à la prise de décisions en rapport à l'évaluation des impacts sur les changements d'occupation de sols (déforestation et glissement de terrain) associés aux activités minières est améliorée par la mise à disposition des connaissances acquises à des institutions non-scientifiques, gouvernementales et sociétés civiles.
- R4.2 Une aide à la prise de décisions en rapport à la transparence dans la gouvernance des ressources minérales et la gestion de l'attribution des licences d'exploitation et d'exploration est améliorée par la mise à disposition des connaissances acquises à des institutions non-scientifiques, gouvernementales et sociétés civiles.

R5 : La gouvernance multipartenariale, le réseautage, la coordination, la concertation entre les parties prenantes et les partenaires ont permis d'assurer le développement de synergies et de complémentarités.

Les recherches coordonnées conjointes entre des universités et centres d'expertise partenaires Nord-Sud et Sud-Sud, l'encadrement et la mobilité des étudiants, participent au suivi et à une vision actualisée des connaissances sur la géologie, les géoressources associées, leur contexte socio-économique, à l'échelle régionale et locale au niveau des sites d'exploitations.

- R5.1 Les changements dans la couverture des sols (déforestation, effondrements et glissements de terrain) associées à des activités minières, à l'échelle nationale et régionale sont suivis par les recherches conjointes des universités et centres d'expertise partenaires.
- R5.2 Une vision actualisée des connaissances sur la géologie et des minéralisations associées, à l'échelle régionale et locale au niveau des sites d'exploitation des géoressources est disponible suite aux recherches coordonnées conjointes des universités et centres d'expertise partenaires.

e) Methodology

La méthode de **"capacity building"** académique proposée sera développée autour de 3 niveaux distincts:

1. la contribution des scientifiques du service GRM aux activités de formation académique de second cycle (MSc) des partenaires africains par le biais de séminaires thématiques et/ou, conférences, enseignées par les scientifiques du GRM et autres "invited guest speakers" ;
2. l'encadrement (académique, logistique et financier) par les scientifiques du service GRM, en tant que (co)promoteur des travaux de thèse (MSc, DEA, PhD) d'étudiants des partenaires africains par le biais d'une programmation de « bourses sandwich académiques », et des visites de terrain des scientifiques GRM ;
3. des travaux de recherche académique conjoints post-doc avec des chercheurs des partenaires africains.

Dans les 3 cas, il s'agira de valoriser l'expertise des chercheurs du MRAC ainsi que sa vaste collection de données, d'archives et d'échantillons.

Un effort particulier sera porté sur la **numérisation des données** (d'archive et nouvellement acquises) en bases de données relationnelles, complétées par des systèmes SIG. Ces bases et ces données seront transférées à chacune des universités et instituts partenaires, prêtes à être valorisées dans les cycles d'enseignement et dans la recherche. Elles pourront contenir des couches SIG documentées (vecteur / trame), des métadonnées, des documents scannés (textes, cartes, croquis, photos) et autres fichiers de données (imageries satellitaires, données géophysiques, géochimiques, …).

Toutes ces données et informations seront le cœur d'un **« centre de connaissances WebGIS »** en ligne qui sera développé en se basant sur les systèmes déjà existants et opérationnels en ligne (DRCMINING, GEOKIVU, MIRECA, Brain Naturalheritage...).

GeoRes4Dev sera finalisé par une **conférence régionale de validation et restitution des résultats** auquel participeront les partenaires au projet et les Services Géologiques des quatre pays, suivi de séances de vulgarisations visant les professionnels, les instances officielles et autres parties prenantes sociétales.

f) Developmental relevance of GeoRes4Dev

Les géoressources (minières, énergétiques, hydriques, géomatériaux) sont indispensables au développement du pays dans lequel elles se trouvent, mais aussi pour l'économie mondiale. Elles sont toutes liées au sous-sol. Une bonne gouvernance de leur exploitation nécessite une bonne connaissance du cadre géologique dans lequel elles se trouvent et du contexte socio-économique-politique de leur exploitation.
GeoRes4Dev renforcera la capacité locale à l'étude, l'enseignement et la connaissance de ces aspects afin de contribuer à l'exploitation durable et en sécurité de ces ressources.
GeoRes4Dev permettra d'évaluer l'efficacité et l'impact de la valorisation de l'expertise et des données d'archives du MRAC dans le domaine spécifique de la transparence et de la gouvernance dans la gestion des ressources minérales.
Le choix des 3 régions–sujets est le fruit de discussions et contacts avec des instituts et organisations locales avec lesquelles le Service GRM du MRAC entretient depuis plusieurs années des contacts et/ou développe des activités de coopération et de recherche.
GeoRes4Dev, exécuté dans le cadre d'un partenariat entre des universités du Sud et le centre d'expertise MRAC, en y impliquant des représentants de la diaspora présents au MRAC et en synergie et complémentarité avec d'autres services du MRAC et autres institutions scientifiques belges et internationales, s'intègre parfaitement dans la volonté de la Belgique de « réorienter des budgets de sa coopération aussi vers des acteurs non politiques et non gouvernementaux ».

g) Long term impact of GeoRes4Dev

Par son travail de formation et de construction de capacités scientifiques, académiques et techniques dans les pays en question, GeoRes4Dev palliera aux lacunes en information de base et en connaissances actualisées des pays producteurs de géoressources. Soutenir les établissements d'enseignement supérieur africains en renforçant leurs capacités en matière de formation, de recherche et de services à la société, est donc un enjeu fondamental. Les effets se feront sentir sur le long terme par l'intégration progressive des nouvelles connaissances par les acteurs locaux responsables de la bonne gestion des géoressources. Les informations largement diffusées seront pérennisées et pourront servir de base aux travaux futurs.
Les scientifiques formés pourront soit renforcer les équipes universitaires et ainsi augmenter la capacité de celles-ci dans leur mission de formation, soit intégrer le cadre de centres de recherches et y développer de nouveaux sujets de recherche.

h) *Sustainability of GeoRes4Dev*

Challenges for sustainability after DGD funding

L'intervention envisagée repose principalement sur le développement du facteur humain par la formation de troisième cycle au niveau DEA, Master et Doctorat et l'encadrement de chercheurs. Cela aura un impact important bien au-delà des termes du projet car ce sera la nouvelle génération de scientifiques enseignants (assistants, chefs de travaux, chercheurs) qui sera ainsi formée. Par leurs activités académiques, ils toucheront un nombre important de jeunes qui en bénéficieront lors de leurs études universitaires.

Un handicap majeur reste le manque flagrant de moyens de fonctionnement des universités partenaires en RDC. Bien que formés, les nouveaux cadres universitaires et enseignants auront des problèmes pour appliquer les connaissances et continuer une quelconque recherche sans être incorporé dans l'un ou l'autre programme de financement.

La situation est meilleure au Rwanda et Burundi, ou des moyens de fonctionnement existent, même s'ils ne sont pas toujours adéquats pour couvrir tous les besoins.

Strategy to tackle those challenges

La possibilité de poursuivre GeoRes4Dev sur une seconde tranche de 5 ans permettrait d'amener de nouveaux diplômés en DEA à poursuivre leur formation en entreprenant un doctorat et à de jeunes doctorants de se confirmer par le biais d'un post-doc.

De nouveaux financements pourraient aussi être trouvés via la coopération belge ou d'autres donateurs pour la recherche scientifique afin de poursuivre des travaux ciblés avec des finalités de publications par les jeunes partenaires formés en collaboration avec le MRAC.

L'organisation régulière (par le MRAC) de conférences sur les géosciences et géoressources dans les instituts partenaires africains et/ou la facilitation de la diffusion/mise en ligne de leurs résultats pourrait contribuer à motiver les jeunes chercheurs formés.

i) *Key stakeholders*

Southern Stakeholder	**Interest (I) & influence (i)**	**Stakeholder engagement strategy**
Universités partenaires et centres de recherche	I- Critical i - High	encadrement académique des étudiants en thèse inscrits à l'université. facilitation administrative et logistique des missions de terrain des étudiants et de l'équipe MRAC Facilitation administrative et logistique de l'implication de l'équipe du MRAC dans le cursus MSc
Organisations géologiques (para)étatiques (service géologique, ministère des mines, cadastre minier, ...)	I – High , i - Medium	délégation de leurs cadres scientifiques pour inscription aux universités en vue de l'obtention d'un diplôme supérieur à l'actuel (ex. : MSc en cas de BSc) (le cas échéant) participation aux travaux de recherche
Agences (para)étatiques provinciales et nationales (gouvernorats etc.)	I: Medium, i: Medium	permis et autorisations de travaux de terrain et de circuler dans la zone / région sous leur responsabilité agents/activateurs décisionnels pour les aspects sociétaux

Opérateurs et organisations minières	I: Medium i: Low	droits d'accès aux zones concédées sous permis
ONG, société civile	I: Medium to high i : Low	accès à certaines sources d'informations relatives à l'impact sociétal des activités minières participation à l'organisation de la conférence de fin de projet activités (de terrain, recherche) conjointes

Northern Stakeholder	**Interest (I) & influence (i)**	**Stakeholder engagement strategy**
Universités et centres de recherche partenaires	I: medium i: high	accueil des étudiants en thèse pour stages / séjours de recherche facilités de laboratoires analytiques

B. PILOTMAB

Luki and Yangambi: Pilot sites for Research and Development in the DRC

Expected outcome 5B: The model function of the Man and the Biosphere (MAB) Reserves Luki and Yangambi in the rainforest biome in DRC for sustainable development is strengthened.

Countries where the activities take place: DRC

Summary

PilotMAB aims to develop activities of research, training and education in the Man and the Biosphere (MAB) Reserves of the DRC within the rainforest biome. The function of these reserves as models for the reconciliation of nature conservation, economy and welfare will be strengthened. As such we will contribute to the sustainable development in the area of the reserves, but, because of the model function, also regionally. As Biosphere Reserves are internationally being considered as laboratories for global change research, we will focus on carbon budgets of the different forest types, through analysis of tree recruitment, growth and mortality. Forest resilience will be addressed through tree trait analysis, completed with pedological and entomological and mammological (bat echolocation) observations.

Training programs will contribute to the capacity building of African researchers and will work on strengthening the managing capacity of the Biosphere Reserves. An educational program will translate research and model function of the Biosphere Reserves to schools.

Keywords: Sustainable resource management, education, monitoring, ecosystem services, global change, threatened ecosystems

DAC sector code & policy markers: 111 / 113 / 312 / 410

Partnerships:

- Resources & Synergies Development (R&SD sarl), Kisangani, **DRC**
  FORETS project
- VVOB – Education for Development, Kisantu-Inkisi, **DRC**
- Ecole Régionale Postuniversitaire d'Aménagement et de Gestion intégrés des Forêts et Territoires tropicaux (ERAIFT), Kinshasa, **DRC**
- Université de Kisangani, **DRC**

RMCA promoters: Hans BEECKMAN, Kim JACOBSEN (Wood Biology), Kurt JORDAENS (Invertebrates, Biology), Isabelle VAN LOO (Education and Culture, Public services), Florias MEES (Surface environments and collection management, Earth Sciences), Emmanuel GILISSEN, Aurore MATHYS (African Zoology, BIOCOL)

Involvement of other Belgian institutes: Botanic Garden Meise

a) *General context*

Development problem that PilotMAB wants to tackle and its sectoral context

PilotMAB will operate under the context of the UNESCO Man and the Biosphere (MAB) program. The MAB program is an intergovernmental scientific program that aims to establish a scientific basis to enhance the relationship between people and their environments. It combines the natural and social sciences with a view to improving human livelihoods and safeguarding natural and managed ecosystems, thus promoting innovative approaches to economic development that are socially and culturally appropriate and environmentally sustainable. As such, the MAB Program: *"Develops and strengthens models for sustainable development in the World Network of Biosphere Reserves (WNBR) and it communicates the experiences and lessons learned. Further it supports evaluation and high-quality management, strategies and policies for sustainable development and planning and supports member states and stakeholders to urgently meet the sustainable development goals (SDGs) through experiences from the WNBR.*" (UNESCO-MAB, 2018).

The MAB program considers the biosphere reserves as laboratories for climate change research and sustainable development. Biosphere reserves are internationally recognized sites promoting

solutions reconciling the conservation of biodiversity with its sustainable use. They provide local solutions to global challenges. The MAB strategy for 2015-2025 *(1) supports explicitly the member states to conserve biodiversity, enhance ecosystem services and foster the sustainable use of natural resources, (2) facilitates sustainability science, education for sustainable development and capacity building and (3) supports mitigation and adaptation to climate change and other aspects of global environmental change.*

Tropical forests occupy a key position for the mitigation of climate change and for economic development. They are carbon stocks and sinks that are vital for the planet and have a more profound influence on weather patterns, freshwater, natural disasters, biodiversity, food, and human health – both in the countries where forests are found and in distant countries – than any other terrestrial biome (*e.g.*, Brandon, 2014). Tropical forests are essential for sustainable growth in Africa, which is home to around 18% of the world's tropical forests. The Congo Basin is the second largest rainforest in the world and presently a persistent carbon sink, rich in biodiversity and an important provider of ecosystem services. It spans across six countries – Cameroon, Central African Republic, Democratic Republic of the Congo, Republic of the Congo, Equatorial Guinea and Gabon. The UNESCO Man and the Biosphere (MAB) reserves of Yangambi (235 000 ha) and Luki (33 000 ha) are both situated within the Democratic Republic of Congo (DRC) and the Congo Basin rainforest (Fig. 5).

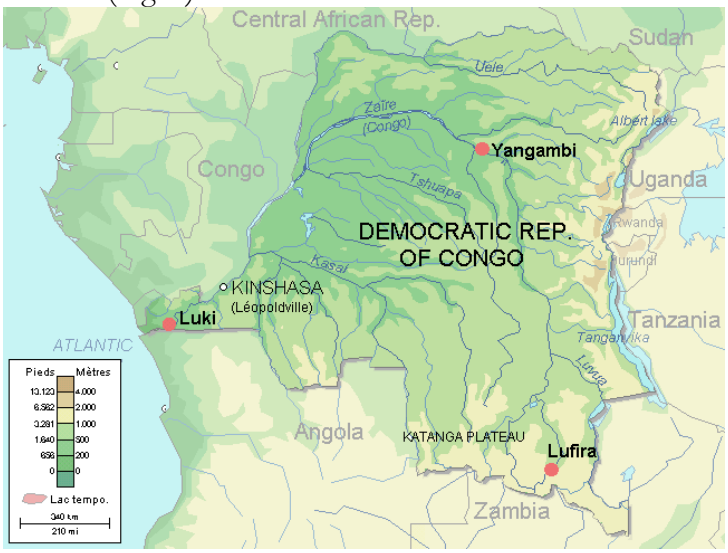

Fig. 5. *Location of the Luki and Yangambi UNESCO MAB reserves in the Democratic Republic of Congo*

Forests are continually changing, due to invasive insects or plants, wildfires, pollution, timber harvest or human development. Deforestation and degradation of tropical forests reduce or halt the flows of ecosystem goods and services, while increasing the vulnerability of local populations and environments.

In recent years, disturbance regimes have changed profoundly in many forest ecosystems, with climate being an important driver of disturbance change. Understanding how such change impacts large forest ecosystems such as the Congo Basin Forest, is critical to managing forests for sustained benefits. Despite their economic, social, and environmental importance, Africa's tropical forests are under threat. Almost 90% of West Africa's coastal rainforest has already been destroyed and deforestation in the Congo Basin has doubled since 1990. Even more important is the gradual forest degradation under high population pressure. Evidence-based management of forests improves the sustainability of human-forest interactions, providing continued sustenance for human populations dependent on this natural resource.

Forestry research in the DRC dates back to the early 20th century, and many of the scientific archives and collections from this period are currently stored at the Royal Museum for Central Africa (RMCA). Since 2004, the RMCA has played an active scientific role in the Yangambi and

Luki biosphere reserves, contributing to insights in many disciplines and to the establishment of local research infrastructure.

UNESCO's MAB reserves are characterized by three interrelated functions (Source : UNESCO and FAO) :

- *Conservation* of the world's biological diversity„;
- *Development* through sustainable resource management in cooperation with local communities;
- *Networking:* The biosphere reserves are linked through a global network, providing facilities for research, monitoring, education and training at the local level as well as for comparative research and monitoring programs at an international or regional level.

Both MAB reserves represent these three roles (conservation, development, networking), which is articulated through a pattern of zonation. The *core zone* (or zones) is strictly protected according to pre-established conservation objectives, allowing monitoring as an important scientific activity. Within its boundaries, it is surrounded by a *buffer zon*e (or zones) where experimental research and training activities can take place. Finally , the *transition zone* is characterized by cooperation with the local population and the development of sustainable resource management practices (Fig. 6). The biosphere reserves are thus unique locations for interdisciplinary research, in interaction with local communities.

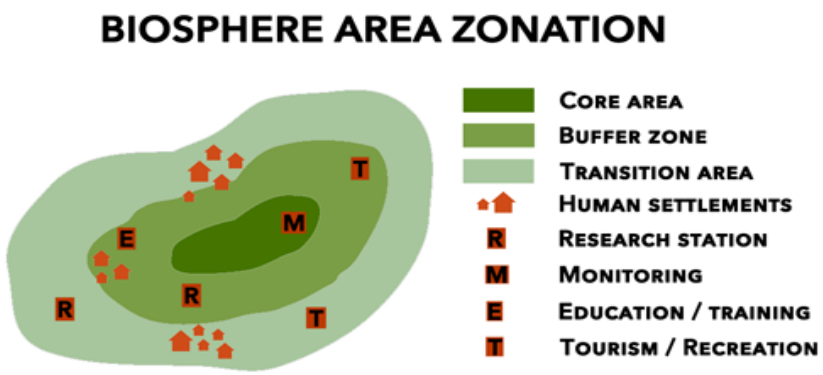

Fig. 6. *UNESCO MAB Biosphere zonation*

The interaction of PilotMAB with the UNESCO MAB program contributes to several Sustainable Development Goals (SDGs).

In particular:

- SDG 2 (Zero hunger): PilotMAB contributes to the conservation of biodiversity and the promotion of sustainable management options to benefit local people. Especially through collaboration with the UNESCO MAB programme, which promotes sustainable and social economy initiatives;
- SDG 4 (Quality education): capacity building through the collaboration with local schools and training of students and professionals;
- SDG 13 (Climate action): The UNESCO MAB reserves are observatories for climate change research, monitoring, mitigation and adaptation, including support of the UNFCC

COP21 Paris Agreement. Targeted research efforts will increase our understanding of the effects of climate change on the African rainforest and help to identify and disseminate good practices. PilotMAB will consolidate and extend the clusters of permanent sample plots in Luki and Yangambi and organize periodic inventories in the permanent sample plots of Luki and Yangambi to maximize the research function of the reserves. Biodiversity research and soil analysis along a mega-transect in the core zone of the Yangambi MAB reserve will further contribute to forest management plans in the context of SDG13.

- SDG 15 (Life on Land): PilotMAB will undertake research to ensure the long-term conservation of the socio-ecological systems (human-forest interactions), in particular through its work on understanding processes that contribute to the restoration and appropriate management of deforested ecosystems.

SDG 17 (Partnerships for the goals): PilotMAB emphasizes a synergistic integration of different disciplines and organizations in order to reach its research and development goals. By strengthening on-going initiatives such as the EU-FORETS project currently underway in the Yangambi MAB reserve, we enhance the impact of both projects.

Capacity constraints and needs of the partner institutions

PilotMAB opts to work with local executive partners R&SD, VVOB DRC and ERAIFT because they are experienced in the field of development cooperation and education in the DRC. Through cooperation with these partners RMCA can more efficiently engage with local actors UNIKIS, INERA, local secondary schools, UNESCO MAB-DRC committee, as well as stakeholders not directly engaged in daily activities of PilotMAB.

In Yangambi, PilotMAB contributes as co-funding to the FORETS project, which has a strong development approach; PilotMAB focuses on research and scientific output. R&SD is the executive partner for the FORETS project and the local executive partner for PilotMAB. In this way, PilotMAB benefits from existing agreements (*e.g.*, MoU) with local actors INERA and UNIKIS. The FORETS project is a project funded by the EU (30 million €, 5 years and to be extended). Partners in FORETS are RMCA, UNIKIS, INERA, R&SD, Ghent University (YPS-project), CIFOR, Botanic Garden Meise, and McGill University Montreal. PilotMAB contributes directly to several specific objectives listed in the FORETS project (Table 1).

Table 1: Specific objectives of the FORETS project for which PilotMAB makes a contribution

Specific Objective	Result
Objective 1 (SO1) Contribute to biodiversity conservation and sustainable development of the Yangambi Biosphere Reserve	OS1R1: The integrity of protected areas and the biosphere reserve is preserved and the biological value maintained or increased through effective management OS1R2: Communities living in the periphery of protected areas are made aware of the need to conserve the natural environment OS1R3: Stakeholders in conservation action benefit from the direct and indirect effects of protection and conservation action
Objective 2 (SO2) Encourage and sustainable agriculture and forestry for socio-economic development of communities near the Yangambi Biosphere Reserve	OS2R3: Increased share of wood energy from forest plantations of fast growing species OS2R4: Ecosystem services in and around protected areas are maintained sustainably for human well-being
Objective 3 (SO3) Mitigate deforestation	OS3R1: Management of Classified, Production and

and increase carbon sequestration through the protection, restoration, enhancement and sustainable management of natural resources in and around the Yangambi Biosphere	Protected Natural Forests is Enhanced for Greater Sustainability OS3R2: Human capacities for sustainable management of forests and biodiversity are improved

In Luki, the executive partners VVOB and ERAIFT are involved in the education component of PilotMAB. In particular, the local partners facilitate interaction with the UNESCO MAB-DRC office (ERAIFT) and with local secondary schools in the transition zone of the Luki reserve (VVOB), considered as +/- 30 km around the core zone of the reserve.

The choice of strong executive partners enables PilotMAB to address research capacity constraints in the domain of climate change research, monitoring of forest dynamics and understanding impact of forest disturbances. Additionally, PilotMAB addresses the lack of relevant scientific information to facilitate development and education projects within the UNESCO-MAB transition zones.

- PilotMAB will introduce state–of-the-art monitoring techniques and innovative research methodologies (*e.g.*, standardized protocols for measurements, time-lapse camera's, impact of forest disturbances on insect diversity and soil properties);
- PilotMAB will train scientists, administrative staff members and teachers and support as such administrative management, scientific reporting skills and improve environmental and sustainability education for local schools in the transition zone of the Biosphere Reserves.;
- PilotMAB will partly be integrated in the FORETS project and will, together with the partners of this project, contribute to the development of the Yangambi Biosphere Reserve. PilotMAB will help FORETS in the establishment of a more informed management plan for the Yangambi Biosphere Reserve.

b) *Background*

Partnership/ownership

The Wood Biology section of the RMCA has worked in both reserves extensively since 2004. This experience has taught us what we can reasonably expect to achieve within the given time frame of 5 years. It has also made clear that a merit-based training system will have the highest chance of success. Through the research activities in Luki and Yangambi we have established reliable partnerships with local and international actors also active in the reserves.
The Education Service has some experience implementing educational projects in the DRC. Since 2004 they have collaborated with the National Museum of Lubumbashi. One of the workshops for schools at the Museum tackles environmental issues ("*Ecologie, SOS environnement!"*). PilotMAB opted to collaborate with a strong local partner (VVOB DRC), with extensive experience in the DRC educational sector.
The Invertebrate section of the RMCA was contacted by UNIKIS in a bid to acquire expertise in the field of entomology and mammology (bat biology). There is a long-standing collaboration between RMCA, CSB and UNIKIS.
Staff members of the RMCA Geology Department have experience in the study of tropical soils, applied in pedological and interdisciplinary studies in various parts of Central Africa.
In an effort to consolidate previous and ongoing research and development initiatives in the DRC, the Wood Biology Division has now partnered with the Education, Invertebrate and Geology sections of the museum.

During the development of the PilotMAB proposal, the RMCA team engaged with the partners to identify implementation strategies that are feasible and relevant to the local context.

Previous experiences between the partners

The PilotMAB complements research carried out during previous projects in Yangambi and Luki, including several training-oriented projects and more research-oriented projects.
With DGD support, the RMCA service of Wood Biology has previously organized group trainings in the DRC and at the RMCA, in the domain of forest ecology (tree growth, wood anatomy, forest inventories). In addition to these group trainings, many individual scientists have been formed, including the ABIC trainings (previous collaboration with **ERAIFT**).
Previous collaboration with **R&SD:** The Xyladate and GeForCo projects (also DGD funding) set up research in Yangambi in order to underpin the policy on management and trade of *Pericopsis elata*.
Several research projects have previously organized field work in the reserves of Luki and Yangambi and/or worked on collection material from these reserves. Projects with Belspo funding: Cobimfo (relation between carbon fluxes and biodiversity in Yangambi), Xylaredd (herbarium and xylarium collections from Luki and Yangambi), Afriford (paleoecology and vegetation history in Central Africa), Biospheretraits (trait-based ecology in Luki and Yangambi) Herbaxylaredd (valorization of botanical collections of Central-Africa; previous collaboration with **ERAIFT**) and Cobecore (valorization of archived information on Central-Africa).

The RMCA (Wood biology) is also involved in the FORETS project (on-going collaboration also with **R&SD**).

c) *Theory of Change*

Management and conservation of ecosystem services improve when knowledge of ecosystem functioning, including the role of human interference, and global change dynamics improve.

The Central-African tropical dense moist forests are crucial for development and play a key role in buffering global climate changes. Their conservation and sound management depend largely on scientific knowledge, technical skills and attitudes of local communities. The logic of the project is to strengthen the scientific capacity, organize trainings to assure technically sound management and impact youth through efforts in sustainability education. The model function for sustainable development of the Biosphere Reserves of Luki and Yangambi will be supported.

Target groups: (1) the larger scientific community, (2) future generations (local schools), (3) local professionals (scientists, students, technical professionals), (4) policy makers

The impact of PilotMAB for each target group:

(1) Central-Africa is, compared to South America and South-East Asia, considered as a major research gap in the domains of carbon dynamics and forest resilience in relation to biodiversity issues. The number of ongoing research projects is low, as well as the scientific output. As far as the DRC rainforests are concerned, there is a particular strong need for research, given the vastness of this biome and its vulnerability.
(2) Conditional for implementing forest protection and management aiming at a sustainable production of good and services, is reliable scientific information. At least as important as research is the attitude of people directly involved in forest management. PilotMAB will explicitly focus on youth education to maximize its chances for long-term impact. The project will work in agreement with the UNESCO policy concerning youth.
(3) Professional forest management involves many skills, including in the field of forest inventories. PilotMAB will train students, officers and staff members of NGOs and private companies to set up forest inventories and to interpret survey results.

(4) Policy makers will be provided with data that are useful for the implementing of existing instruments like there are the REDD+ program, CITES, EU-timber regulation, FLEGT and the US Lacey Act. A key contribution for the UNESCO MAB reserves in the DRC is also the assistance with the draft of the Periodic review, a document that is required for the DRC-MAB reserves to remain within the World Network of Biosphere Reserves.

d) Expected results

R1: Strengthening scientific research capacity

- Students and professionals are trained during several training events in research related to the Congo Basin forest ecosystem, incl. inventory and carbon stock measurements, soil properties and Diptera diversity.
- Research on the tropical forest ecosystem is conducted, topics incl. tree growth, wood-fuel, non-timber forest products, forest resilience, phenology, vegetation types, carbon stocks, soil (fertility, structure and composition as it relates to forest resilience), and biodiversity research on selected Diptera families is conducted to investigate their potential role as indicators of forest disturbance and pollination.

R2: Strengthening physical and virtual diffusion of scientific research results to the larger scientific community

- A reference collection is established for target groups, including phenotype type profiles of tree species (spectrum of functional traits) and the selected Diptera families.
- Existing websites are improved or new websites are developed.
- Online educational/didactic material concerning forest ecology and sustainable use of natural resources developed. In function of Strategic Objective 6, where the target audience is local schools, we will coordinate with the VVOB DRC to provide output such as infographics, posters and so forth, which are more directly relevant for use in the school context.
- Online and open access to data generated by the project: includes the upgrade and updating of the RMCA xylarium database (for species relevant to the Yangambi and Luki regions), and relevant historic data uploaded to online international data repositories and the project website.
- Research results are published in international peer-reviewed (open access) journals and presented at international conferences.

R3: Awareness raising towards the general public

- Belgium (RMCA): permanent/temporary exhibits benefit from results generated during project: interviews with scientists, guided visits, a workshop for visiting school children, press release when appropriate.
- Wider dissemination of research results through press releases, presentation at conferences, blog updates and outreach activities where appropriate

R4: Support to good governance, based on the scientific results

- Policy briefs for enforcement of forest conservation mechanisms and tropical timber trade.
- Contribution towards to development of a management plan for the Yangambi reserve (in collaboration with the FORETS project).

R5: Development of synergies and complementary activities among partners through multi-partner governance and coordination

- Participation in meetings of international and regional stakeholders such as CITES, EU-FLEGT, CBFP, UNESCO, and others.
- Knowledge dissemination via a website, frequent blog updates, conference participation, data repositories, and others.

e) *Other strategic objective*

See SO6: *Target groups have acquired the knowledge and skills necessary to promote and contribute to a fair, inclusive, sustainable and equitable world.*

f) *Methodology*

Research

Research will be carried out to support our understanding of tropical forest ecosystems along three main themes:

- **Climate change**
  What? Inventory in existing permanent forest plots and in newly created plots in Yangambi (17 ha rainforest, 2 fieldwork missions in 2019 and 2021) and in Luki (8 ha rainforest and 40 ha savanna, 2 fieldwork missions in 2020 and 2022). Measurements will be done on trees (subsequent censuses for growth analysis, pith-to-bark cores for age determination and micro cores for analysis of cambial activity) and associated soil samples will be taken next to the permanent sample plots. Associated soil samples will be taken (bulk samples for standard characterization, undisturbed samples for micromorphological analysis). Data will be shared with Forestplots.net, a large international data repository.
  Where? Buffer and Core
- **Forest resilience**
  What? The phenology of trees (flowering, fruit setting and leaf fall) and growth will be followed up using dendrometers, time-lapse cameras and sampling of (micro)cores: +/- 40 trees in Yangambi and +/- 20 trees in Luki.
  Where? Buffer area.
- **Impact of natural and human disturbance on biodiversity**
  What? Along a **mega-transect (MT)** of 100 km (see Fig. 7), observations will be made on tree species composition, soil characteristics, camera traps for animal observations, and selected Diptera families to investigate their potential role as indicators of forest disturbance and pollination (incl. establishment of a reference collection). The functional ecology of bat sensory systems will be studied and how it is effected by forest disturbance. This transect will cut through numerous forest types of the Congo Basin, including disturbed and undisturbed forest. Observations on forest ecology and species composition will assist in the development of a sustainable forest management plan for the Yangambi biosphere reserve.
  Where? Core (Fig. 7)

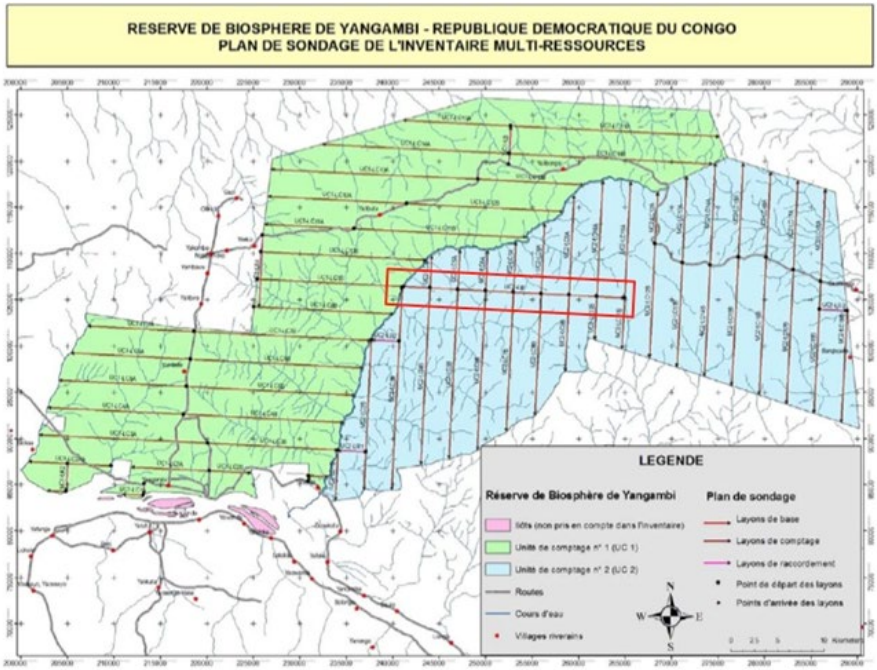

Fig. 7. *Map of the Yangambi Biosphere, with indication of the mega-transect (red box)*

Education

- **Merit-based training program** (MSc and PhD): The merit-based training program implemented during PilotMAB aims to select the best candidates for in depth training and scientific research activities. The merit-based training program will be conducted in the forest of the Yangambi reserve. This training program follows a protocol, which has previously been successfully implemented during research and training activities of the RMCA (Wood Biology section) in Yangambi. Students and professionals will be selected from applications sent to the local partner. The selected candidates will include an equal number of male and female candidates, and selections will be based on a reference letter and credentials suitable for the training event. The training event will last two weeks, including classroom and fieldwork sessions. There are two merit-based training events.
  MBT 20p – wood biology, candidate pool of 20 students and professionals At the end of this training event, the 3 best candidates will be selected, following test results, and invited for an in depth training period in Belgium at the RMCA (wood biology). After the in-depth training period, the best candidate will be selected to start a PhD at the University of Kisangani. During the PhD research, the candidate will spend 6 months a year in Belgium for training and research purposes.
  MBT 10p – entomology and geology, candidate pool of 10 students and professionals: A group of 6 candidates will be trained in entomology, and 4 candidates will be trained in soil sampling and geology. At the end of the training the best candidates will be selected to assist with data collection along the mega-transect. An opportunity to pursue a MSc diploma or a position as technical staff are both possible outcomes for candidates participating in MBT 10p.
  Training in Bat biology - A group of 1 Congolese PhD student and 4 Congolese MSc students will be trained in bat biology, with a focus on echolocation and sonar structure; data collection will be carried out along the mega-transect in Yangambi, contributing to insights in the effects of forest disturbance on bat sensory systems (functional ecology). Selection of these students will be carried out during their academic coursework at UNIKIS with our local expert (Prof. Guy Gembu). Care will be taken to give equal opportunity to female scientists and to provide a transparent selection procedure.

- **Mega-transect training for 50p (MT50p):** this training event aims to create a technical team able to perform multi-resource inventories along the mega-transect in the core zone of the Yangambi biosphere reserve. Applicants can apply for different profiles (*e.g.*, compass-reader, botanic staff, tree climbers, etc.). This training program follows a protocol, which was previously successfully implemented during Wood Biology activities in the context of the FORETS program in Yangambi. The trained staff from this past training event is constantly involved in on-going activities, making a new training program necessary within the context of PilotMAB.
- **Thematic training events** for local students and professionals in Yangambi and Luki
  Thematic training1 (20p): Topic wood sampling (Yangambi) – selection of participants will be based on merit, with equal participation of male and female candidates. Target audience: students, officers and staff members of NGO's and private companies.
  Thematic training2 (20p): Topic tree identification (Yangambi) – selection of participants will be based on merit, with equal participation of male and female candidates. Target audience: students, officers and staff members of NGOs and private companies.
- **Thematic training3 (15p)**: Topic capacity building for the UNESCO-MAB office (Kinshasa) – selection of participants will be based on merit, with equal participation of male and female candidates. Target audience: Policy makers, UNESCO-MAB staff, affiliated persons. In preparation of this training event, a <u>needs assessment</u> will be carried out together with the Paris UNESCO Office for Networking: Biosphere Reserves and Capacity Building (NBC).
- **Collaboration with local schools**: In preparation of this activity, a <u>needs assessment</u> will be carried out to identify schools that are willing to participate in the program, their specific needs and opportunities to integrate themes concerning sustainable forest management and the environment in their curriculum. Activities will center on train-the-trainer workshops, interschool events, doors open days and the development of didactic materials.

<u>Knowledge dissemination</u>
Outreach and knowledge dissemination is an integral component of PilotMAB. Regular blog updates, press releases at pivotal moments, as well as punctual reporting via specific scientific channels (*e.g.*, conferences, journals, contribution to museum exhibitions, etc.) will contribute to the public visibility of PilotMAB activities. On an international level, increasing the visibility of the UNESCO MAB reserves in Central-Africa is particularly relevant.
A project website will be set up in the first year to promote PilotMAB didactic materials, guidelines for fieldwork and scientific documentation concerning forest ecology and sustainable use of natural resources.
All data generated by the project will be made available via open access repositories and data papers, after valorization in scientific publications. Online and open access to data generated by the project: includes the upgrade and updating of relevant parts of the RMCA xylarium database, and relevant historic data uploaded to online international data repositories and the project website
Research results will be published in international peer-reviewed (open access) journals and presented at international conferences.

g) <u>Developmental relevance of PilotMAB</u>

Forest management aiming at a sustainable production of goods and services are key for development. Forests assure environmental protection and are resources for energy (wood fuel, charcoal), timber, food and medicines. These products can be extracted from the wild in a potentially sustainable way, provided that there is reliable information on carrying capacity of the forest ecosystem (*e.g.*, data on growth increment, so that logging will not cut more wood than

what is being produced). Forests also generate income through international markets, such as carbon credits and precious timber products.

PilotMAB contributes to development cooperation through its goals to disseminate knowledge and skills to local stakeholders: local schools play a key role for sustainable development, as children are the future generations. The merit-based training program will transfer knowledge and skills to motivated professional participants (*e.g.*, customs officers, technical staff) and students (in liaison with UniKis & ERAIFT), to be implemented in the context of natural resource management activities or private enterprise (*e.g.*, CFT).

Because of the focus on the MAB concept PilotMAB will be well embedded in the region. More specifically the link to the FORETS project will assure an optimal local embedding in the Tshopo province. The interaction with schools and the post-graduate training facility of ERAIFT will embed the project within the Kongo-Central province.

h) Sustainability of PilotMAB

Challenges for sustainability after DGD funding

DRC remains a logistically difficult country to operate in due to the dysfunctional governmental structures, the many challenges with infrastructure and frequent security risks. At the same time, the vastness of the Congo Basin (the second largest rainforest in the world) and its role in mitigation for global warming, means that research on forest ecosystem processes and forest resilience from this region are crucial to understanding global systems. In recent years, conditions have been favourable enough to initiate numerous research activities in the region. If conditions remain more or less the same, we can expect increased interest from Congolese and international researchers in the Yangambi and Luki Biosphere reserve, as the region remains underrepresented in most global analyses.
The Wood Biology service has numerous examples of students who followed a training workshop and have continued on to fulfil a successful scientific career – thus supporting local research capacity and policy. Training of professionals in the local timber industry will enable the development of FSC standard logging practices – currently unavailable in the DRC.
The educational component of PilotMAB hopes to contribute to long-term improved understanding of the value of sustainable forest management by directly addressing future generations.

Strategy to tackle those challenges

All scientific output will be shared through open access channels, in order to provide continued access by the scientific community. Didactic materials will also be provided online through the website, and afterwards, this material can be recuperated and updated by follow-up initiatives/projects and museum workshops.

The contribution of scientific data originating from the Congo Basin rainforest to international data repositories and global systems analyses, will further increase interest for other researchers in the UNESCO MAB reserves.

i) Key stakeholders

Southern Stakeholder	**Interest & influence**	**Stakeholder engagement strategy**
Management of the Biosphere Reserves of Luki and Yangambi (administration, committees, government)	Responsible for maintaining the status of the reserves and reporting to UNESCO	Will be invited to participate in a thematic training workshop addressing their specific needs; Will receive adapted progress reports.
Research organisations active in the Biosphere Reserves (INERA, UNIKIS, UNIKIN)	Locally present with scientific and technical staff; using research infrastructure	Will be invited to develop research priorities, will be associated to research. INERA and UNIKIS are associated formally through agreements made in the context of the FORETS project; the local expert in mammology is a professor at UNIKIS (Prof. Guy Gembu)
Private logging companies (*e.g.*, CFT)	Implementation of FSC-standards demands a scientific approach to establish management plans for sustainable timber production	Will be invited to participate in training events
Centre de Surveillance de la Biodiversité (CSB) de l'Université de Kisangani (UNIKIS)	Infrastructure to facilitate actions and benefits for biodiversity in the DRC, for capacity building and conservation purposes	Will receive vouchers of the Diptera species collected along the mega-transect in Yangambi. Skills transfer in bat biology research techniques (incl. documentation materials, taxonomic ID kits, etc)
Secondary schools	Responsible for the education of future generations living in the immediate environment of Luki Biosphere reserve.	School teachers will be trained according their specific needs. Will contribute to the development of and receive didactic material for awareness raising of pupils.
Northern Stakeholder	**Interest & influence**	**Stakeholder engagement strategy**
UNESCO MAB program	Robust international network active on the same topics as the project	Will be involved in trainings, will get regular reports and updates
RBINS	Contributes to management of CSB	Will receive updates and access to reference collections managed at CSB

C. FISHBASE AFRICA

FishBase for Africa: data dissemination, capacity building & fisheries

Expected outcome 5C: *Up-to-date scientific information about African freshwater and brackish water fish is freely available and ichtyological research capacity is strengthened , mainly for the benefit of developing countries, in order to achieve a correct identification of fishes and provide tools pertinent for studies on fisheries, aquaculture and conservation.*

R1: Strengthening scientific research capacity
R2: Strengthening physical and virtual diffusion of scientific research results to the larger scientific community
R3: awareness raising towards the general public
R4: Support to good governance, based on the scientific results
R5: Development of synergies and complementary activities among partners through multi-partner governance and coordination
For further information, see SO 1, FishBase Africa's main strategic objective.

D. MBISA CONGO II

Expected outcome 5D: *The research capacity on fish diversity and the sustainable conservation of fish in the Congo basin is strengthened through sustainable North-South-South partnerships.*

R1: Strengthening scientific research capacity
Fish, as part of the rich and diverse aquatic environments they are an integrated part of, are more than "natural resources" only, a reality that reveals itself through the very study of these fauna's and engenders "a care for what we love".

R2: Strengthening physical and virtual diffusion of scientific research results to the larger scientific community
Published and shared knowledge also creates awareness, of a.o. the presence of highly diverse and endemic fish faunas within the Congo basin as a whole, a prerequisite for sustainability.

R4: Support to good governance, based on the scientific results
The formulation of policy briefs in order to raise attention to the importance of fish resources diversity for sustainable development.

R5: Development of synergies and complementary activities among partners through multi-partner governance and coordination
Humans, as "natural resources", i.e. as well-informed and aware beings, and organised in collectives are the best "local resource" to ensure such a sustainable development within their local environments.

2. Synergies and complementarities

A. GeoRes4Dev

With other Belgian actors

Actuellement, des grottes du Bas-Kongo sont l'objet d'études de la part d'une équipe de biologistes belgo-congolaise menée pour le MRAC par Emmanuel Vreeven (MBISA II) avec le soutien de la DGD. Des travaux sur les mêmes sites en karstologie pourraient leur apporter des éléments utiles pour leurs recherches sur les poissons aveugles et certains travaux pourraient aussi être effectués en synergies. Cette synergie pourrait aussi nous être utile pour certains éléments d'information, des accès facilités et des explorations communes éventuelles.

Les sites du « knowledge centre » du MRAC développés avec l'aide de la DGD seront complétés par les nouvelles données incorporées dans le nouveaux système base de données/SIG élaboré pour ce projet.
Le site miroir du Knowledge centre du MRAC, hébergé à Kinshasa dans les infrastructures du CRGM, sera complété avec les nouveaux développements du projet.

With other actors

- Universiteit Gent: expertise reconnue pour les aspects en rapport avec la genèse et la caractérisation des gisements métallifères. (COMICODE, LUALABA)
- Katholieke Universiteit Leuven: expertise reconnue pour les aspects en rapport avec la métallogénie et pour les aspects de santé publique, épidémiologiques en rapport avec l'impact sur les populations de l'industrie minière ou extractive. (COMICODE, LUALABA)
- Stellenbosch University: université avec expertise et équipements de pointe, contrôle structural des minéralisations et caractérisation des minerais, avec un intérêt porté sur les cratons congolais et tanzanien et leurs pourtours. (LUALABA)
- Université Marien Ngouabi de Brazzaville: connaissance d'éléments géologiques complémentaires dans la prolongation des terrains étudiés au Kongo Central et régions avoisinantes – mêmes contextes et mêmes défis sociétaux. (KONGO)
- Carter Center (Lubumbashi): ONG de renommée mondiale; recherche sur la promotion de la transparence dans la gestion du secteur minier (LUALABA)
- Coopératives et compagnies extractives: accès à leurs sites pour les travaux de terrain géologiques et sociétaux (KONGO, COMICODE, LUALABA)
- Rwanda Mines Board: fait fonction de service géologique. Les activités au Rwanda se feront en association avec des géologues du RMB (COMICODE)
- Service Géologique du Burundi: Les activités au Burundi se feront en association avec des géologues du SGB (COMICODE). Les cartes numérisées au 50.000ème dans le cadre du projet CTB 2016 (Enabel) sont conservées et gérées par l'Unité Géomatique du Service Géologique. La préparation des travaux de terrain pour les stages de cartographie et les thèses qui seront réalisés se fera sur des shapefiles avec les géologues de cette unité géomatique formés dans le cadre de ce projet. En retour, toutes les observations faites pendant ces stages et ces thèses, susceptibles de contribuer à la mise à jour de la carte géologique seront obligatoirement transmises à l'Unité Géomatique du Service Géologique.
- Centre de recherches géologiques et Minières (Kinshasa) partenaire de recherche de longue date pour les études géologiques dans la province Kongo central et la région de Kinshasa; facilitateur et collaborateur lors des travaux de terrain. Les activités de recherche se feront en association avec le CRGM. (KONGO et infrastructure banques de données internet – Knowledge centre MRAC)
- Ministère des Mines – service géologique de la RDC (Kinshasa): nouveau partenaire potentiel: le SG-RDC est en voie de développement au sein du ministère dans le cadre d'un projet de la Banque mondiale

B. PilotMAB

With other Belgian actors

- VLIR: On-going project FORMONCO II (VLIR-Team) – this project investigates the role of nutrients for forest growth and resilience and provides synergies at the research level.
- BELSPO: YPS (Yangambi Pôle Scientifique): "Fluxtower project": This project aims to establish carbon budgets at the level of the ecosystem through direct gas measurements from a tower. This project is complementary with the carbon measurement through tree measurements and forest inventories, planned by PilotMAB. Data will be exchanged for mutual calibrations and up-scaling of measurements.
- ETAGE, VVOB's current DGD program (2017-2021) focuses on promoting entrepreneurship in technical secondary agricultural education in Kongo Central, including the promotion of sustainable agricultural practices at school level.

With other actors

- EU FORETS: development and research capacity building in the Tshopo province
- UNESCO MAB: concept of reconciliation of development and conservation, model of climate change research and sustainability of use of the forest
- UNESCO Youth Forum: this forum provides young people with the opportunity to present their concerns and ideas to the UNESCO General Conference, every two years, to ensure that the voices of youth are properly represented in programmatic decisions made by the Member States.
- Congo Basin Forest Partnership: networking possibilities with stakeholders form the private sector, governments, NGOs, sponsors, international institutions and scientists.