

Research Application Summary

**African Centre of Excellence for Innovative Rodent Pest Management and  
Biosensor Technology Development (ACE IRPM and BTM- Rat-Tech)**

Makundi, R.H. & Massawe, A.W.

Pest Management Centre, Sokoine University of Agriculture, P.O. Box 3110, Morogoro, Tanzania

**Corresponding author:** [apiamas@yahoo.com](mailto:apiamas@yahoo.com)

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**Abstract**

Rodents are some of the most serious mammalian pests the world over. However, their economic and social impact is not quantified in Sub-Saharan Africa. Moreover, while some of the zoonotic diseases attributed to rodents such as Lassa fever and bubonic plague are endemic in rural Africa, occasionally leading to serious outbreaks, more often than not, rodent-borne diseases are not recognized, and hence are inadequately managed. The African Centre of Excellence (ACE) in Innovative Rodent Pest Management and Biosensor Technology Development (IRPM and BTM) will enhance scientific knowledge, Technology and Innovation (STI) on Rodent Pest Management in Africa. The IRPM and BTM activities will incorporate biosensor technology using trained rats for land mine detection and support their operational deployment to complement existing technologies to free mine afflicted lands in Africa and elsewhere and release these for safe use by humans (settlement, agriculture, mining, livestock, etc.). Novel diagnostic approaches are a key component to tackling Tuberculosis epidemic, yet in resource-limited settings in Africa, the latest advanced diagnostic technologies are lacking. Trained rats are efficient and reliable TB diagnostic biosensor technology. The ACE for IRPM and BTM will build capacity through training at the MSc and PhD levels in rodent taxonomy, ecology, innovative STI in rodent management and biosensor technology. IRPM and BTM will establish basic and applied research programs for African scientists to pursue high-impact projects in rodent management, understanding the impact of zoonotic diseases on communities and their mitigation, and how best to use biosensor technology for detecting landmines and diagnosis of diseases. A minimum of 60 Master of Science and 32 PhD students will be trained and faculty exchange between regional higher education institutions will be supported. Short courses will be conducted focusing on dissemination of sustainable STI solutions to rodent problems in Africa. Research will be focused to solve regional rodent problems that impact on rural communities in Africa.

Key words: biosensor technology, rodent management, Sokoine, zoonotic diseases

**Résumé**

Les rongeurs sont parmi des ravageurs mammifères les plus dangereux dans le monde entier. Cependant, leur impact économique et social n'est pas quantifié en Afrique subsaharienne. En outre, bien que certaines des maladies zoonotiques attribuées à des rongeurs telles que la fièvre de Lassa et la peste bubonique soient endémiques en Afrique rurale, occasionnant parfois des épidémies graves, le plus souvent, les maladies transmises par les rongeurs ne

sont pas reconnues et donc mal gérées. Le Centre d'Excellence Africain (CEA) dans le développement novateur de la lutte antiparasitaire des rongeurs et du développement de la technologie des biocapteurs (IRPM & BTD) améliorera les connaissances scientifiques, la technologie et l'innovation (STI) sur la lutte antiparasitaire en Afrique. Les activités de l'IRPM & BTD intégreront la technologie des biocapteurs à l'aide de rats entraînés pour la détection des mines terrestres et appuieront leur déploiement opérationnel pour compléter les technologies existantes afin de libérer les terres affligées par les mines en Afrique et ailleurs, etc.). Les nouvelles approches diagnostiques sont un élément clé pour lutter contre l'épidémie de la tuberculose, mais dans les régions à ressources limitées en Afrique, les dernières technologies de diagnostic avancées font défaut. Les rats formés sont des technologies efficaces et fiables pour le diagnostic de la tuberculose. Le Centre de l'IRPM & BTD renforcera les capacités grâce à la formation aux niveaux Maîtrise et Doctoral en taxinomie des rongeurs, écologie, STI innovantes dans la gestion des rongeurs, et dans la technologie des biocapteurs. L'IRPM & BTD mettra sur pied des programmes de recherche fondamentale et appliquée pour les scientifiques africains afin de poursuivre des projets à impact élevé sur la gestion des rongeurs, comprendre l'impact des zoonoses sur les communautés et leurs atténuations, et la meilleure façon d'utiliser la technologie du biocapteur pour détecter les mines terrestres et le diagnostic des maladies. Un minimum de 60 formations de niveau Maîtrise et 32 doctorants seront formés et les échanges du personnel académique entre les établissements d'enseignement supérieur régionaux seront soutenus. Des cours de courte durée seront consacrés à la dissémination de solutions STI durables aux problèmes des rongeurs en Afrique. La recherche sera axée sur la résolution des problèmes régionaux des rongeurs qui ont un impact sur les communautés rurales en Afrique.

Mots clés: la technologie des biocapteurs, la gestion des rongeurs, Sokoine, les maladies zoonotiques

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## Introduction

Rodents (rats and mice) are arguably some of the most neglected and yet serious mammalian pests the world over. Rodents attack and damage crops grown in the field, as well as stored crops in homes, warehouses and factories (Makundi *et al.*, 1999). This damage, in addition to contamination of food is a big loss across the value chain. Despite this understanding, accurate assessment of losses caused by the rodents in pre- and post-harvest agriculture is difficult to obtain for most sub-Saharan African countries (Makundi *et al.*, 2005). Rodents are also problematic in cities where their harbouring and feeding habits result in damage to sewage and drainage systems, building structure, damage electrical cables and gas piping systems. Rodents are, in addition, a serious nuisance due to their messy droppings and urine that contaminate food and drink in homes and warehouses. Also, rodent bites of humans and other animals are not uncommon. The economic and social impact of such damage occasionally makes the news when, for instance, expensive hospital equipment is damaged or buildings burn down due to rodent damaged cables, but such damage is rarely quantified. Rodent outbreaks in Africa are often devastating in terms of crop losses,

resulting in famine (Leirs *et al.*, 2010).

Zoonotic diseases, associated with rodents, such as Lassa fever, leptospirosis and bubonic plague are endemic in rural Africa, occasionally leading to serious outbreaks. But more often than not, rodent-borne diseases are not recognized, and as such, are often inadequately managed. Consequently, thousands of poor rural people die from rodent-borne diseases across Africa each year. Given the fact that rodents can transmit more than 60 diseases to humans and other animals, besides damaging food and exacerbating sanitation problems, rats and mice are a major concern for the society (Gratz, 1997). Despite this, research on rodent pest and its management is absent in many African countries. What are also not in place are technologies to mitigate the impact of rodent pests on poor rural communities, particularly reducing crop damage, infrastructure damage and the transmission of zoonotic diseases.

Research on pest rodents is typically carried out by relatively isolated African researchers, and even fewer institutions have teams of experts studying the behaviour and innovative management of rodents. This low capacity for innovation has led to a situation whereby low investment has been accorded to rodent research, which explains the limited awareness and poor documentation of the scale of rodent pest problems on the African continent. However, this situation could be changed in Africa through the objectives and priorities of the proposed African Higher Education Centre of Excellence (ACE) in Innovative Rodent Pest Management and Biosensor Technology (IRPM and BTM). This initiative would enhance scientific knowledge, Technology and Innovation (STI) on Rodent and Pest Management in Africa. Furthermore, it will promote inter-regional scientific research collaboration and better coordination in rodent pest management among policy, researchers, agricultural and public health outreach services in the government, non-governmental (NGO) and private sectors across the African continent. In a nutshell, the proposed ACE will combine the strengths of individual institutions across East, Central and Southern Africa to help build the sustainable STI centre. Inter-regional innovation network will increase the quality of science produced through cross-training and the sharing of best practices that address the multiplicity of problems caused by rodents for African communities.

Building Africa's research capacity to tackle rodent pest problems by developing innovative and appropriate solutions could be one of the most important interventions of the 21st century across the continent to reduce poverty and improve people's livelihoods. The multiple adverse impacts of rodents on human lives place these pests in a relatively unique position compared to other pest and disease carriers faced by African communities. Therefore, reducing rodent pest numbers can have a much larger impact than that of any other single pest (Makundi and Massawe, 2011). In agriculture, rodents are both a pre-harvest, and post-harvest pest problem, causing major threats to food security, and safety. In the post-harvest sector, small-holder farmers keep their grain in stores and granaries that are rarely rodent proof. Food and water contamination with rodent urine and faecal matter is a major source of food borne bacterial, viral and parasitic diseases of humans. Rodents also selectively eat the germ of stored grain, which reduces its nutritive content. In fact

post-harvest loss for many African farmers is typically 5-20%. The yield losses vary from region to region, depending on the crops grown and the local rodent population. For East Africa, at least, losses are reported to be as high as 48% for maize, sorghum and pulses (Makundi *et al.*, 1991).

Despite being a well-recognized problem throughout the world, there has been relatively little research on rodent pest management, since the advent of anticoagulant rodenticides in the 1950's. Rodents have been ignored mainly because of a lack of comprehensive data on their true impact. Inadequate and irrational adaptation of rodent control measures to particular situations often results in treatment failures, leading to apathy, frustrations and hence widespread tolerance of rodent pests in African communities. Many rural farmers suffer from low awareness, ingrained defeatism when trying to control rodents and acquiesce to rodent damage. Damage is difficult to quantify at the household level because individual experience cannot be based on an "absence of rodents" (control) to make comparisons. In a global context, therefore, rodent pests are a valid poverty indicator because the households most exposed, and proximal, to rodents are usually the poorest as they lack the tools and knowledge to manage rodents effectively. Recent research suggests that small-holder farmers can sustainably reduce rodent pests in their environment in ways that farmers, themselves, perceive as cost-beneficial.

**Public health challenge: Rodent borne zoonoses.** Bubonic plague is one of the zoonotic diseases for which rodents are hosts and is endemic throughout Sub-Saharan Africa, where greater than 90% of the world's human cases now occur. Plague is among the notifiable diseases to the World Health Organization, which has categorized this disease as a Class 1 quarantinable disease. Cases of plague tend to be confined within endemic foci with seasonal outbreaks of human cases, but outbreaks can and do occur sporadically outside the foci as has recently occurred in Tanzania and Madagascar (Makundi *et al.*, 2008). Plague can remain quiescent for many years, and threats of human outbreak remain in many African countries where plague-positive wild rodents are found. Leptospirosis is another important rodent borne disease with highest burden in Africa affecting 100 people/100,000 annually (Machang'u, 1985; Machang'u *et al.*, 1997) (SPMC has established strong leptospirosis research capacity in sub Saharan Africa through its collaboration with the Royal Tropical Institute (KIT) that is a WHO/OIE/FAO Reference centre for Leptospirosis Research). The ACE will enable the SPMC to address leptospirosis problems in the region. Lassa fever, which is endemic to some parts of West Africa, is an even more serious disease than plague because of the high mortality associated with this viral haemorrhagic fever and lack of treatment or prevention. Although many questions about rodent-borne zoonosis remain unanswered, it is clear that the expansion of agriculture into previously wild habitats, land use changes and global climate change will influence the patterns of the rodent borne zoonoses in terms of prevalence and incidence. The need for more research in rodent pest management is clearly an important priority for the ACE's target countries in East and Southern Africa. Most African countries will acknowledge rodents as a problem across the agriculture, environment and health sectors, but few have strategies and action plans in rodent management. Given its long history of applied rodent research in all these sectors

the SPMC in Tanzania stands out as a unique exception. SPMC potential to grow into a centre of excellence in this field in Africa, and beyond, is feasible subject to availability of technical and financial support needed for this growth.

**Advancing detection rats technology: Biosensor technology development Landmine detection.** Despite major efforts to eliminate the harm of landmines and Un-exploded Ordinances (UXO) in former war-torn areas in Africa, these devices continue to claim the lives of children, women and men worldwide. Landmines threaten civilian lives and impede post-war reconstruction of societies, which is a major political and social challenge for mine-affected countries and the international community. A collaborative project based at SPMC, since year 2000, has trained and internally accredited more than 150 rats for landmine detection (SUA –APOPO Annual Report 2014). The incorporation of this technology into the ACE activities, will continue to refine the biosensor technology and support the operational deployment of these rats to maximize their use in demining initiatives. The collaborative initiative, established between SUA and the Belgian organization (Acronym: APOPO) continue to search for local, cost effective solutions to detect and remove landmines from affected areas. The ultimate goal is to utilize the mines detection rats to complement existing technologies to free mine afflicted lands in Africa and elsewhere and release these for safe use by humans (settlement, agriculture, mining, livestock, etc.). The SUA-APOPO project welcomes partnership with national and international organizations, and governments and NGOs for global mine action support around the world.

**Biosensor technology for disease diagnosis.** Tuberculosis (TB) is a global leading cause of death, which has assumed threatening proportions, especially after the HIV/AIDS pandemic since the 1980s. Despite improvement in TB case finding, there is so far not a single established diagnostic technique able to screen large populations accurately, rapidly, cost effectively and routinely. Novel diagnostic approaches are a key component to tackling the TB epidemic, yet in resource-limited settings in East, Central and Southern Africa, the lack of latest advanced diagnostic technologies are sadly a serious challenge. High cost, lack of replaceable parts, inadequate supplies of consumable and electric power are among the limitations. Currently, accurate and efficient diagnosis of subclinical TB is, among others, the most pressing health problems in many African countries. Rats trained at the SUA-APOPO Project have been deployed for TB diagnosis trials in Tanzania and Mozambique while other countries in southern Africa have indicated their interest in this technology particularly because TB cases have increased proportionately with HIV infections. The deployment of rodents as biosensors is a scientific innovation that has potential application also in forensics and border security (Mgode *et al.*, 2012; Mgode *et al.*, 2015). The ACE IRPM and BTD being established at Sokoine University will intensify research to refine this technology and promote its application to higher levels as well as in new areas.

**Objectives of ACE IRPM and BTM**

<b>ACE's Broad objectives</b>		<b>ACE's specific objectives</b>	
1	To strengthen science, technology and innovation about rodent biology and management and contribute to African development sustainably by enabling institutions to address key indicators of poverty through reduction of the adverse impact of rodents on agricultural production systems and food security	(i)	To develop Africa appropriate innovations through R and D that will re-duce the impact of rodents on people's livelihoods.
		(ii)	To build and strengthen Africa's STI capacities across a range of special-ties that will enhance socio-economic development by influencing policy issues, promoting knowledge dissemination and enhancing technical competence to deliver sustainable rodent pest management.
2	To improve multi-stakeholder interactions to overcome bottlenecks in the current rodent pest management service provision and develop African-appropriate innovations that will reduce the impact of rodents on peoples' livelihoods.	(iii)	To build Africa's capacities by enhancing across a range of specialties related to ecologically-based rodent management including: population dynamics, chemical ecology, animal behavior, taxonomy, social anthropology, economics, agronomy, post-harvest storage and quality assurance, technology adoption, end-user participatory research and training and awareness enhancement programmes.
		(iv)	To enhance collaboration and cooperation at the national, interregional and international levels by providing a platform to promote rodent research, training of experts and research output focused on state-of-the art technologies for reducing the negative impact of rodents on the welfare and health of communities in East and Southern Africa
		(v)	To develop, disseminate and apply rodent based biosensor technology in the fields of land mine detection, diseases diagnostics and other applications
		(vi)	To investigate the fundamental ecological factors pertaining to zoonotic disease outbreaks in Africa and integrate the knowledge of the ecology of the rodent-reservoirs and vectors and vectors-pathogen system in improving human health.
		(vii)	To identify STI priorities for rodent related research and formulate policies that will improve rodent management and reduce the impact of rodents on food security;
		(viii)	To develop national and international capacities to deliver, manage and monitor Africa-appropriate innovations for rodent management;
		(ix)	To increase awareness among decision makers and the general public about the multi facet impact of rodents on people's livelihoods in order to influence STI investment priorities.

**Partners and their roles**

The ACE in IRPM and BTM is based at Sokoine University of Agriculture, Tanzania. The Centre will provide the overall leadership and coordination of the activities including providing the core training for the MSc and PhD. However, the Centre will be supported by a number of national, regional and international knowledge centres as outlined in Table 1 below.

Table 1: Partners and their roles in implementation of the African Higher Education Centre of excellence in rodent management at Sokoine University of Agriculture

Serial no.	Name of Partner Institution	Role in addressing the developmental challenge
1.	Pest Management Centre	<ol style="list-style-type: none"> <li>1. To lead studies on Biology and Ecology of Rodents</li> <li>2. Provide leadership for the ACE for IRPM and sBTD</li> <li>3. To lead on the development of smallholder-based rodent management technologies and models that can support the scaling-up of technology transfer and promotion of ecologically-based management strategies</li> <li>4. Evaluate current knowledge, attitudes and practice at household, institutional and national levels with regards to impact and management of rodents.</li> <li>5. Guidance on basic and applied research on rodent ecology, taxonomy and ecologically-based rodent pest management in agriculture</li> </ol>
2	National Institute for Medical Research	Support research on use of African Pouched Giant rats as biosensors for diagnosis of Tuberculosis
3	National Rodent Control Centre (NRCC)	Outreach activities particularly evaluation and dissemination of rodent management technologies
4.	Mekelle University, Ethiopia	<ol style="list-style-type: none"> <li>1. Ecological Studies of Rodents in Uganda and Ethiopia</li> <li>2. Academic advisory services and supervision of postgraduate students (MSc and PhD)</li> <li>3. Testing technologies for Innovative Rodent Pest Management</li> <li>4. Improve opportunities for African field biologists to receive training</li> </ol>
5.	Busitema University, Uganda	<ol style="list-style-type: none"> <li>5. Provide a forum for the exchange of STI amongst field scientists that do not normally have the occasion to meet</li> <li>6. Develop professional contacts that lead to long-term collaborations, sharing of expertise</li> <li>7. Provide students with life-changing experiences that influence their professional development and networks</li> <li>8. Provide teachers with in-service training and training materials</li> <li>9. Raise awareness with the general public and policy makers about rodent pest issues through first-hand accounts</li> <li>10. Build capacity of civil society groups on rodent management delivery options</li> </ol>
6.	University of Greenwich, Natural Resources Institute (UoG-NRI), United Kingdom	<ol style="list-style-type: none"> <li>1. To promote mechanisms and frameworks for integrating traditional knowledge and modern scientific approaches in rodent pest management for greater developmental impact.</li> <li>2. To be the key advisor to the ACE for IRPM and BTD on R and D and technology transfer</li> </ol>
7.	University of Antwerp (UA), Belgium	<ol style="list-style-type: none"> <li>1. Support the training of postgraduate students in the fields of modelling rodent populations for ecologically based management.</li> </ol>

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|  | 2. Research Supervision for postgraduate students in the fields of zoonotics   |
|  | 3. Key advisory services on technical matters related to the ACE performance   |
| 8. Department of Psychology, Cornell University, USA                                   | 1. Student supervision PhD and BSc.)<br>2. Animal behaviour and Ecological studies   |
| 9. APOPO   | 1. Development and dissemination of biosensor technology for land mine detection in Mozambique, Angola, etc.<br>2. Research on biosensor technology to diagnose tuberculosis and other diseases in Tanzania, Zambia, Mozambique and Ethiopia.<br>3. Support for field operations in different countries (Mozambique, Angola, Zimbabwe, etc.<br>4. Key decisions on use of biosensor technology |
| 10. KIT Biomedical Research – WHO/FAO/OIE Leptospirosis Reference Laboratory           | Support technically on research on leptospirosis   |
| 11. Sumitomo Chemical East Africa Ltd (Arusha, Tanzania) and Sumitomo Chemical – Japan | Jointly develop and market rodent repellents as innovative technology to protect crops and prevent house infestation by rodents  |
| 12. PEE PEE (Tanzania) Ltd   | Evaluation of hermetic storage and marketing hermetic storage technologies such as air impermeable bags for storage of grains.   |
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**Role of Regional partners in research activities.** The ACE IRPM and BTM will be addressing rodent biology, ecology, management and technologies for reducing the impact of rodents on communities in Eastern and Southern Africa. Thus research activities will be regional to address the regional challenges. The regional partners (Uganda and Ethiopia) shall identify researchable issues within their countries that can be funded by the ACE. Ecologically-based rodent pest management of crop pests and rodents involved in transmission of human diseases is the most pressing need in the Africa. Each regional partner shall be required to address this issue by proposing research activities to generate ecological knowledge on local rodent species which are pests, and innovative technologies for their management. Each partner regional institutions shall conduct, in addition to other proposed activities, the following: (i) Fundamental ecological factors pertaining to zoonotic disease outbreaks (plague, leptospirosis, and toxoplasmosis) and integrate the knowledge of the ecology of the rodent-reservoirs and vectors and vectors-pathogen system in improving human health. (ii) Population ecology of rodents in crop ecosystems and influence of landscape ecology on rodent populations. (iii) Trials on innovative technologies for rodent pest management (e.g., fertility control, hermetic storage, bio-control, etc). In order to accomplish these activities, both faculty and PhD students shall be engaged in these research activities leading to joint authorship of published articles.



**External advisory group.** The ACE for IRPM and BTM will have an External Advisory Group consisting of at least three independent, internationally respected experts from the international institutions who have acquired wide experience in developing ecologically-based rodent management and other technologies for rodent pest management. The main task of the members of the advisory group will be to provide independent evaluation of progress of IRPM and BTM. They will also be consulted for advice on project questions, invited to share their views on specific projects progress in the ACE for IRPM and BTM and generally participate in discussions about project strategies and externalities that affect project priorities. The advisory group will have no formal responsibilities in the ACE other than those specified under external partners.

Where applicable, partners will receive funding for their activities averaging 15-25% of the project funding. Partners will be actively engaged in implementing the ACE or IRPM and BTM as specified in their roles. The key partners will be invited to attend the annual meetings with their costs covered under the budget allocated to them. The National associate partners will be invited to annual meetings, which can be covered by the ACE for IRPM and BTM budget. In addition, the partners will as much as possible take advantage of the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM, see [www.ruforum.org](http://www.ruforum.org) for details), a network of 66 African universities in 26 African countries, to share lessons and experiences with the wider higher education centre in Africa. The ACE will also use the RUFORUM platform to support recruitment of regional students.

### **Expected Results of the ACE IRPM and BTM**

The following will be the major outcomes of the activities of the ACE for IRPM and BTM;

- (i). Increased interaction, cooperation and collaboration of faculty and scientists working in the field of rodent pest management in the East and southern African region: Adoption of sustainable technologies for rodent pest management that are tailored to specific areas within the region.
- (ii). Trained experts at the MSc and PhD levels to undertake basic and applied research in East, Southern and Central Africa addressing STI in diverse fields including taxonomy, ecology, pest management, etc.
- (iii). Sustainable technologies for rodent management introduced.
- (iv). Increased capacity of communities in the African region to respond to rodent outbreaks and the African scale.
- (v). Factors that determine the occurrence, persistence of zoonotic diseases on a local scale.
- (vi). Reduced mortality and morbidity due to rodent borne zoonotic diseases such as bubonic plague.
- (vii). Trained national teams of experts to screen TB in their communities using the bio-sensor technology.
- (viii). Increased capacity by nations within the African region to rapidly cope up with tuberculosis epidemics in cities and vulnerable groups such as refugee in camps, prisons, mining camps, agricultural estates, etc.
- (ix). Large areas cleared of landmines in affected countries, and made accessible for social and economic activities.
- (x). Joint publications in scientific journals with high impact factors.

### Concluding Remarks

The ACE IRPM and BTM provides opportunity to build research capacity to address rodent problem in Africa. It draws on national, regional and international partners to support delivery of the planned activities. Operationally, it is planned to link the ACE IRPM and BTM with other ACE I and ACE II centres in Africa, and to the wider RUFORUM Network of universities.

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### References

- APOPO. 2014. Annual Report 2014. Published by APOPO.
- Gratz, N. 1997. The burden of rodent-borne diseases in Africa south of the Sahara. *Belgian Journal of Zoology* 127: 71-84.
- Leirs, H., Sluydts, V. and Makundi, R. 2010. Rodent outbreaks in sub-Saharan Africa. pp. 269-280. In: Singleton, G.R., Belmain, S.R., Brown, P. R. and Hardy, B. (Eds.). Rodent Outbreaks: Ecology and Impacts. International Rice Research Institute, Los Banos, Philippines.
- Machang'u, R.S. 1985. Leptospirosis: Current reports on epidemiology in tropical and subtropical Africa. *Vet. Bull.* 7: 20 – 22.
- Machang'u, R.S., Mgode, G. and Mpanduji, D.G. 1997. Leptospirosis in animals and humans in selected areas of Tanzania. *Belg. J. Zool.* 27 (supplement. 1): 97 – 104.
- Makundi, R.H., Mbise, T.J. and Kilonzo, B.S. 1991. Observations on the role of rodents in crop losses in Tanzania and control strategies. Beitrage zur Tropischen Landwirtschaft und Veterinarmedizin. *Journal of Tropical Agriculture and Veterinary Science* 29 (4): 465 - 474.
- Makundi, R.H., Ogue, N.O. and Mwanjabe, P.S. 1999. Rodent pest management in East Africa – An ecological approach. pp. 460 – 476. In: Singleton, G., Hinds, L. Leirs, H., and Zhang, Z. (Eds.), Ecologically-based Rodent Management. Australian Center for International Agricultural Research, Canberra, Australia. (ISBN 186320 2625).
- Makundi, R.H., Bekele, A., Leirs, H., Massawe, A.W., Rwamugira, W. and Mulungu, L.S. 2005. Farmer's perceptions of rodents as crop pests: Knowledge, attitudes, and practices in rodent pest management in Tanzania and Ethiopia. *Belgian Journal of Zoology* (Supplement). 135: 153-157.
- Makundi, R. H., Apia, H., Massawe, W., Mulungu, L.S., Katakweba, A., Mbise, T. J. and Mgode, G. 2008. Potential mammalian reservoirs in a bubonic plague outbreak focus in Mbulu District, northern Tanzania, in 2007. *Mammalia* 72 (3): 253-257.
- Makundi, R.H., Apia, H. and Massawe, W. 2011. Ecologically-based rodent management in Africa: Potential and challenges. *Wildlife Research* 38 (7) : 588-595.

- Mgode, G. F., Weetjens, B. J., Nawrath, T., Cox, C., Jubitana, M., Machang'u, R. S. and Kaufmann, S. H. 2012. Diagnosis of tuberculosis by trained African giant pouched rats and confounding impact of pathogens and microflora of the respiratory tract. *Journal of Clinical Microbiology* 50 (2): 274-280.
- Mgode, G. F., Cohen-Bacrie, S., Bedotto, M., Weetjens, B. J., Cox, C., Jubitana, M. and Kaufmann, S. H. 2015. Mycobacterium genotypes in pulmonary tuberculosis infections and their detection by trained African giant pouched rats. *Current Microbiology* 70 (2): 212-218.