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# Rodent Proliferation in Urban and Agricultural Settings of Sub-Saharan Africa – Part 2. Towards Integrated Management Strategies, and Beyond

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# Rodent Proliferation in Urban and Agricultural Settings of Sub-Saharan Africa – Part 2. Towards Integrated Management Strategies, and Beyond

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**Abstract:** The use of synthetic chemical rodenticides is the most commonly practiced rodent management method in sub-Saharan Africa which results in health and environmental risks without any significant improvement in terms of reducing rodent pest populations sustainably. In this paper, which is a second part of a diptych, we advocate for better control of the use of synthetic chemical rodenticides in urban and agricultural settings in sub-Saharan Africa, as well as a shift towards more sustainable and environment-friendly rodent management approaches, such as the Ecologically-Based Rodent Management (EBRM), as a realistic alternative to synthetic rodenticides. The EBRM approach relies on a solid knowledge of pest rodent biology, ecology and behavior as well as the use of a pool of rodent management actions implemented through community-based interventions to ensure sustained reduction of rodent pest populations down to economically and sanitary acceptable levels. EBRM is expected not only to ensure reducing the social impacts of pest rodents in cost-beneficial ways, but also the risks of rodents and synthetic rodenticides to human health and the environment.

**Keywords:** Africa; ecologically based rodent management; field rodents; pest management; rodent control; rodenticides; rodents; synanthropic rodents doi:10.20944/preprints202301.0275.v2



## 1. Ecologically-Based Rodent Management – an environment-friendly alternative to synthetic chemical rodenticides

This paper is the second part of a diptych. In the first one [1], we tried to attract attention to the deleterious effects of synthetic rodenticides that are massively used in Sub-Saharan Africa against pest rodents in both agricultural and urban settings. Here, we advocate for better control of the use of synthetic chemical rodenticides, as well as a shift towards more sustainable and environment-friendly rodent management approaches, such as the Ecologically-Based Rodent Management (EBRM), as a realistic alternative to synthetic rodenticides. EBRM relies on a good understanding of the diversity, behavior, ecology and population dynamics of rodents as well as the perceptions, uses and practices of human populations towards rodent pest species [2-6]. It mobilizes a panel of various rodent management methods that are integrated into robust community-based implementation protocols adapted to local situations. These methods may comprise biological (e.g., predators, botanical rodenticides or repellents), ecological (e.g., habitat management), mechanical (e.g., selective trapping), agronomic (e.g., crop rotation) and cultural (e.g., hunting, rodent-proof storage facilities) actions that must sometimes be implemented at different key times of the year, (e.g., rodent population dynamics, local socio-economic and agricultural calendars). It entails the local appropriateness and full integration of proactive methods into routine agricultural, conservation and environmental management practices as an alternative to the reactive use of synthetic chemical rodenticides that usually follows high rodent infestations and damages. Importantly, following its very community-based nature, EBRM incorporates local socio-economic and environmental constraints potentially associated with pest rodent management (or absence of management) by local stakeholders, whatever they may be (e.g., farmers, inhabitants, firm owners, as well as local, national and international authorities and decision makers). Thus, EBRM is expected to provide science-guided solutions to (1) the lack of effective, affordable and integrated conventional methods for sustainable management of rodent pests, (2) the risks associated with the use of chemical rodenticides, including the evolution of resistance by rodents against the chemicals, and (3) the increased focus on human and environmental health-friendly value chains in the context of the requirement of increased food production.

Championed essentially by Grant Singleton and his colleagues, EBRM has been successfully implemented and evaluated in the last two decades in Southeast Asian agro-ecosystems, especially rice farming systems [2, 6-8], where self-appropriateness and extend of EBRM by local farmers seems to be largely favored by socio-cultural structures and habits that greatly facilitate community-based approaches [4]. EBRM was trailed recently in rural areas of Southern and Eastern Africa at a much smaller scale [9-11] and, to our knowledge, attempts are still lacking in a wide range of countries, especially in Central and West Africa (see Supplementary material, S1 Table). In addition, the big picture has not been drawn yet [12], so arguments to anticipate its acceptation and self-appropriateness by African farmers are lacking and extra studies are still required to evaluate further the pertinence and long-term sustainability of EBRM in rural Africa. Furthermore, we are not aware of any EBRM activity formally tested in African urban settings, but see [10] for a first attempt focusing on household sanitary aspects.

Here, we will build on various examples from Senegal, Mauritania, Mali, Niger, Benin and Ethiopia, beyond the well documented case studies that have taken place in Southern and Eastern Africa (S1 Table), to shed light on obvious needs and opportunities for improvement in the field of rodent management, especially EBRM, in sub-Saharan Africa.

## 2. EBRM in African cities and their immediate peripheries

At the urban and sub-urban levels, rodent infestations are projected to intensify in sub-Saharan Africa since 1.2 billion people in Africa will be city-dwellers by 2050, with most of them living in densely populated, precarious and unhealthy areas [13, 14]. In urban precarious areas, commensal rodents are omnipresent inside or immediately around human dwellings, with enormous infestation rates and health risks associated with rodent-borne zoonotic diseases. For instance, in a series of 376 villages and towns that have been investigated from 1983 to 2014 in Senegal, rodents were trapped in 94.6% of the 700 indoor sampling sessions [15]. In Nigeria, a cross-sectional study involving 500 residents in the city of Osogbo showed that 90.9% of slum dwellers had seen rodents in their homes, 55.4% declared seeing rodents moving freely inside their home, and 43.3% observed a rodent at home within the last 24 hours [16], thus highlighting the very close promiscuity between rodents and human beings. In Niamey (Niger), out of 178 human dwellings investigated in 18 districts between December 2009 and May 2011, 134 (75.3%) were found to be infested with small mammals, while 96.5% of 170 inhabitants interviewed there mentioned rodent-associated problems in their dwellings [17]. In Bamako (Mali), small mammals were captured in 350 of 403 (86.8%) houses sampled in 11 districts of the six city center communes (sampling conducted between October 2021 and October 2022), and between 79-94% of households surveyed in eight peripheral districts (100 households/district; surveys conducted between March and May 2022) reported seeing rodents in their dwellings in the last 30 days (S. Ag Atteynine, L. Granjon *et al.*, unpublished data). In Cotonou (Benin), during repeated sampling sessions in two deprived districts within the city (10-12 households per district, sampling conducted between November 2016 and June 2018), rodents were captured in respectively 58 of 68 (85.3%) and 64 of 65 (98.4%) trapping sessions [18]. In a 2018 survey involving 36 residents from the two districts, majority of the residents (91.7%) reported having seen rats in their homes [19].

Despite their abundance and everyday nuisances in urban settings in Africa, coordinated actions against urban rodents have been only taken in response to cases of large epidemics in major cities (e.g., Lassa in Lagos, plague in Antananarivo and Dakar in the early 20$^{th}$ century), see [20, 21]. Such reactive interventions are resource-demanding, usually planned by health authorities with limited background about rodent biology and behavior, and essentially relying on the massive application of chemical rodenticides. Besides, rodent management is conducted by the individual households, in most cases using chemical rodenticides sold in informal local markets and typically in a total absence of coordination between neighboring households. This results not only in non-negligible extra costs to households (for estimates of rodenticide-associated economic burden, see [11, 19]), but also in a very poor success in reducing rodent populations, due to factors such as the lack of effective control products and/or application protocols as well as immediate re-infestation of treated areas by rodents from untreated neighboring houses [22]. Note that in such urban socio-ecosystems, EBRM has been poorly tested [23]. Urban areas represent very peculiar sociological (e.g., socio-cultural heterogeneity, difficulties to identify recognized and representative local leaders, complex house ownership and rental systems) and ecological (e.g., densely populated and highly human-modified habitats, numerous but scattered spots of food stock and garbage dumping sites, highly prolific commensal rodents with poorly documented eco-ethologic and population dynamics characteristics) environments. These specific features of urban areas require a thorough identification, testing and evaluation of specifically-designed EBRM tools for this type of socio-ecosystem. The task appears huge, and we believe that coordinated pluridisciplinary interventional research is urgently needed in this aspect.

## 3. EBRM in rural Africa, with special emphasis on Sahelian region

### *3.1. The Ethiopian EBRM experience*

In rural areas, some EBRM programs have been tested. In the Amhara Region of Ethiopia, MetaMeta, a Dutch social enterprise working with smallholder farmers in several countries, introduced an EBRM package [24, 25] in 2019 for smallholder mixed cropping systems (growing wheat, barley and potato coupled with animal husbandry), where farmers and extension workers claimed rodent damage was severe (>25%) before the introduction of EBRM (our unpublished data). Long before the EBRM introduction, farmers in the region had already organized into 63 Watershed User Associations (WUAs), registered under the regional government and are responsible for watershed management (mainly soil and water conservation practices) as a community, covering a total area of about 120,000 ha. Watershed groups involve all farmers who own adjacent crop fields and grazing lands in a particular watershed (catchment) area. These groups had a well-organized

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system in place and were best suited to operating community based EBRM at an appropriate scale for rodent management. The first and most important part of the EBRM activities was to take time for training and action planning co-constructed with the WUA committees, who then passed it on to all their members. In action planning they incorporated the timing of the EBRM actions in the lean season (i.e., when rodent populations are still at lower density) and the importance of collective action (e.g., they made by-laws that a household who did not join in a collective activity such as flooding rodent burrows, would pay a penalty). Because there was already established strong sense of community via the WUA, this was quite effective. The activities implemented as part of the EBRM package included maintaining loose soil and water conservation structures (particularly stone bunds and terraces which have been claimed to provide shelters for the rodents), clearing grasses and bushes near the bunds and terraces to create an open strip of land of 1-2 meter that increases the visibility of rodents to predators, deep ploughing, flooding and plugging rodent holes and burrows, setting up stone traps, using domestic cats (mainly in homesteads), and storing grains in locally made, rodent-proof storage structures. These activities were combined with the application of a newly developed bio-rodenticide (a plant origin product proven to toxify rodent pests, our unpublished data waiting for patenting procedures for publication) implemented in the form of campaigns in the watershed areas, where all members of the watersheds were involved, starting from the time of land preparation to harvesting. In close collaboration with rodent scientists, MetaMeta developed the bio-rodenticide (BR) using a combination of two locally available botanicals [26, 27] (Figure 1). Its operational viability was extensively tested in Ethiopia on three rodent species (*Arvicanthis niloticus, Mastomys awashensis, Rattus rattus*), both in laboratory conditions (cumulative mortality rate at 96 hours ≥ 74%, median lethal dose LD50 = 11.35g for a combination of two botanical extracts dosed at 120 mg/g) and in the fields. Pending publication of the full results in a subsequent paper, our post-implementation survey with the members of the watershed campaigns indicated that farmers perceived that rodent damages had been cut by a magnitude of up to 50% after two years of EBRM practicing. The survey also indicated that through horizontal learning, the uptake of the EBRM activities has increased by up to threefold in the neighboring watersheds not included in our EBRM campaigns. The demand for the BR has increased significantly and about a dozen women small-scale enterprises (SMEs) have been trained by MetaMeta in 2020 and 2021 to produce package and sell the BR to fellow farmers at local scale at an affordable price (the production cost of the BR by the SMEs was about €1.50 per 250g jar and the cost of the BR per hectare was estimated at €7-10). In northern Ethiopia, farmers average annual pesticide expenditure ranged between €3-12/ha [28]. The authors also noted that farmers spend up to €9 to purchase a kitten to prevent stored-grain damage by rodents. In sub-Saharan Africa, farmers are willing to pay €3-10/ha for effective rodent management products per cropping season [29].


**Figure 1. A label from the prototype bio-rodenticide developed in Ethiopia.** Versions in English and in Amharic illustrate the importance in terms of efficiency and safety of having packaging written in local languages.

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Unlike chemical rodenticides, BRs are inherently less harmful to the environment and non-target species since their active ingredients are largely volatile and quickly degradable, hence less persistent in the food chain. Although this probably deserves rigorous investigations, unlike synthetic chemical rodenticides, BRs usually are composed of a complex panel of co-acting molecules that work together to toxify rodents. This makes them less prone to the development of resistance against them. Efforts are underway to ensure wider use of the BR in Ethiopia as well as to extend this innovative approach to other African countries. There is enormous scope to make EBRM the standard rodent management method in Ethiopia and beyond.

### *3.2. Opportunities for EBRM in Sahelo-Sudanian Western Africa*

In West Africa, such experiences are almost non-existent, although some isolated attempt could already provide elements to more integrated EBRM strategies *sensu stricto*. For instance, the traditional pitfall traps (the co-called "Kornaka" traps) used by Sahelian farmers appears to be promising to reduce pest gerbils' abundances in extensive pluvial millet fields in Central Niger beyond reliance on chemical rodenticides (e.g., 37 captures in 3 nights with 49 Kornaka traps, equivalent to a capture rate of 25.2%, compared with 22 captures in 5 nights with 256 locally-made wire mesh traps, equivalent to a capture rate of 1.7%: the Kornaka traps were thus 15 times more effective than the wire mesh traps [30]). Due to a shortage of chemical rodenticides, Crop Protection officers in Ogo (Matam, Senegal) have experimented pitfall traps in a 10-15 days' participatory farmer action in four localities in 2021 (B. Diouf, pers. comm., Feb. 2022). This small scale, preliminary demonstration resulted in conspicuous rodent captures and was perceived as promising by most participants, although its effectiveness has not been precisely quantified and some farmers also mentioned this method was more labor intensive than simply applying chemical rodenticides (B. Diouf, pers. comm., Feb. 2022). In Northern Senegal, we have made some important progress on our understanding of rodent problems and opportunities for EBRM implementation. For example, it is now clear that some elements within irrigated rice fields are highly favorable to rodents (e.g., piles of thorn bush made into hedges, Figure 2 A; heavily grassed dikes, bunds and irrigation canals; see Figure 3A-B). Thus, in terms of risk, estimated by the Adjusted Odds Ratio, the abundance of each of the two main rodent pests of rice crops (*Mastomys huberti* and *Arvicanthis niloticus*) estimated over a decade of monitoring in the Delta of River Senegal increases significantly by a factor of 1.02 for each additional percentage of vegetation cover [31]. Pest rodents also take advantage of uncultivated parcels or edges of fields where they take shelter and reproduce, and from which they invade rice fields [31], thus pointing towards the potential value of a better land preparation and management of fallow lands adjacent to cultivated fields to avoid rodent infestation and damages. Conversely, other situations appear as clearly unfavorable to rodents, corresponding to those where shelters are rare, and where vegetation are controlled on dikes and other structures (Figure 3 C-D). From there, possible EBRM elements could include: replacing piles of branches of thorny bush made into hedges and random shrubs grown around fences (that provide ideal shelter for rodents) by tight edge made from fish nets, recycled pans of greenhouse sheets or braided used drip pipes (as already practiced by some farmers), or made of more enduring wire-mesh or barbed wire (Figure 2 B-F); mowing grass on dikes and irrigation channels; avoiding planting crops on dikes; eliminating crop residues and practicing tillage after crops.

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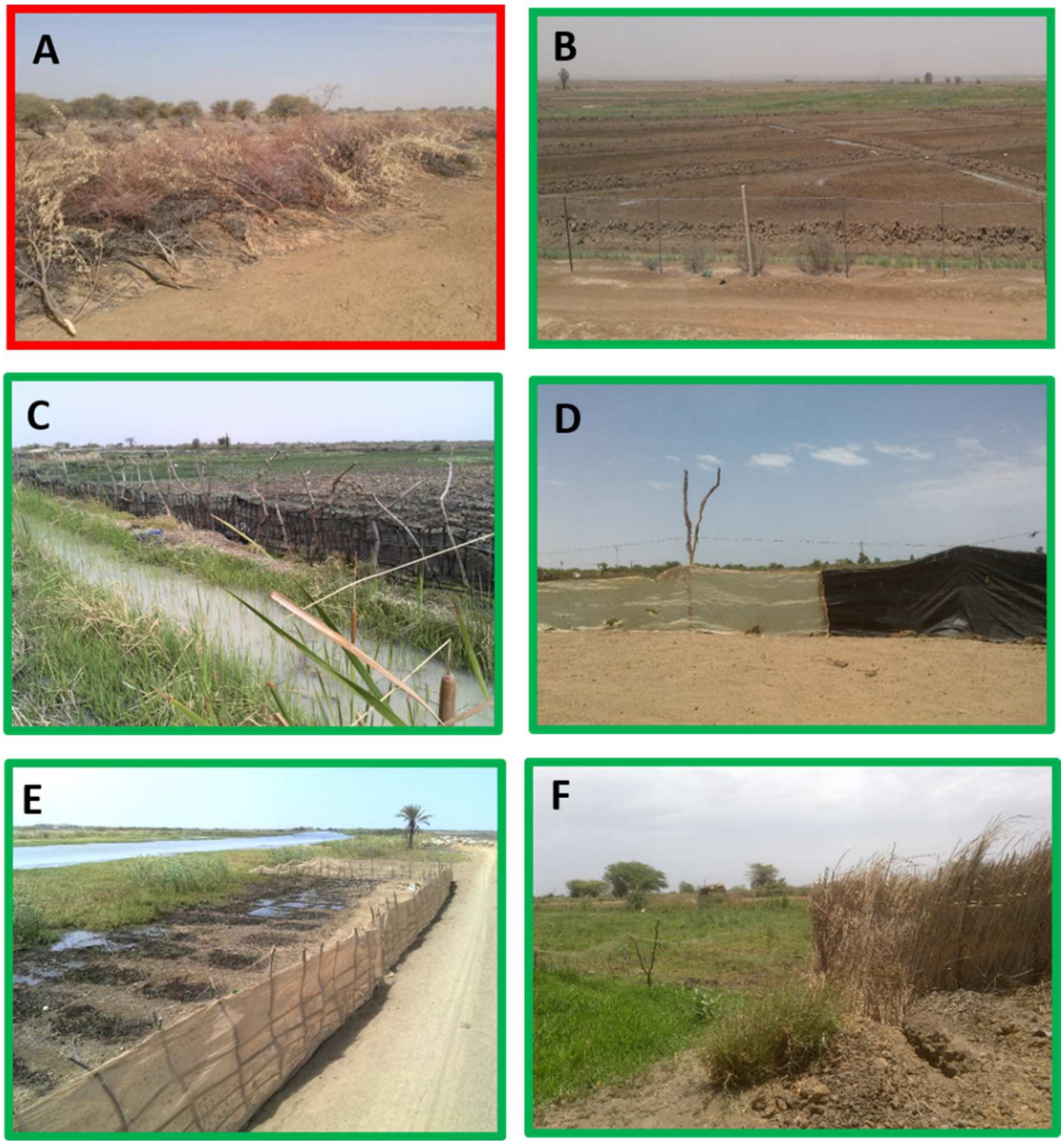


**Figure 2. Examples of fences in cultivated plots from the valley of River Senegal, Mauritania and Senegal.** A, a pile of thorny branches that constitutes an ideal refuge for rodents; B-F, a diversity of fences that are unfavorable to rodents: B, a wire-mesh fence, on the edge of an off-season rice paddy, after cleaning the dikes and bunds; C, used drip pipes braided into fence; D, a fence of barbed wire covered with recycled pans of greenhouse and of agricultural mulching sheets; E, a fence made of fish nets overlaid with recycled pans of greenhouse sheets; F, wire mesh covered with fish nets (left) and weaved palisade made of harvested proliferative aquatic *Typha* (right).

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**Figure 3. Illustration of contrasted situations in irrigated areas of the Senegal River delta.** A, B, presence of rodent-friendly vegetation on dikes (red arrows) along irrigation canals; C, D, controlled vegetation on dikes (green arrows) along canals that increases the visibility and access of rodents to predators.

The recurrence of major damages to food crops since the 1970's, due to recurring events of particularly high rodent pest abundances has led West African states and/or international institutions to call on emergency for external expertise on multiple occasions to assess the critical situation and propose sustainable strategic rodent management actions [32-36]. The rodent outbreak observed in 2020-2021 along the Senegal River valley is very illustrative in that the lessons that could have been learned from historical events and the numerous scientific knowledge accumulated over the years have not been translated yet into concrete, effective and sustainable management actions that could have allowed this crisis to be anticipated and managed efficiently and on time. Though probably too late, an interdisciplinary assessment, combining for the first time both socio-economic, biological and ecological approaches, was implemented by FAO [37]. Out of a total area of 111,643 ha cultivated with rice, 14 to 37% were reported to have been affected by rodents depending on the region. This would represent an estimated loss of around 84,000 tons of paddy rice for a single cropping year or 6 to 35% of the total expected rice production depending on the region. The production loss represented an estimated US$ 31.4 million, directly affecting nearly 40,000 households or 270,000 people (i.e., 11 to 14% of the population of these regions) [37]. Subsequent appraisals activities have outlined a lack of expertise and logistical constraints in national Crop Protection services/agencies, which therefore constitute a leverage for future targeted interventions. In Senegal and Mauritania, Crop Protection officers have recently been trying to raise awareness to encourage farmers to carry out preventive measures against rodent pests in their fields, but it is probably necessary for the actions to be better planned and coordinated in scale, incentive-based and accompanied by follow-up assessments for their effectiveness. Recently, an integrated rodent management strategy has been formulated in Mauritania [38]. Therefore, FAO has supported two interventional projects in Mauritania and Senegal to raise awareness about the dangers of using synthetic rodenticides for rodent control and the presence of alternative integrated management strategies based on the knowledge of rodent population dynamics in space and time. An illustrative example of actions implemented in 2022 in Mauritania involved mechanical/physical management methods such as cleaning rodent hideouts in dykes in rice fields, installation of mosquito nets on the dykes over rodent burrows, mechanical killing of rodents trapped by the mosquito nets while flooding of burrows, and use of pitfall traps (Figure 4). These actions were combined with strong incentives from national and regional authorities where the allocation of inputs (e.g., fertilizers) was conditional on the participation of farmers in the management activities, and where fines were eventually considered for refusal to participate. In Mali, the Rodentology Laboratory of the Institute of Rural Economics also aims to conduct operational research activities in both urban and rural areas in line with public policies. The aim is to evaluate the impact of four methods of rodent management on agricultural yields (optimized chemical control, trapping sessions associated with collective actions implemented by farmers before the rodent abundance annual peak, use of the repellent effect of predator odors, testing the efficacy of a local plant identified as potentially toxic to rodents through farmers' knowledge).


**Figure 4. Awareness-raising and mechanical rodent control actions in Mauritania carried out in 2022.** A, cleaning of dykes; B, installation of mosquito nets on the dykes over rodent burrows; C, flooding of burrows with water and mechanical killing of rodents trapped in the nets; D, result of a session of mechanical control.

Other innovative methods that have been developed in Southeast Asia and tested at small scale in East Africa, may have a promising future in Western Africa. For example, the community trap barrier system (cTBS) is an in-field rodent management method that can be used by rice farming communities. It involves the establishment of a rectangular "trap crop" three weeks before the rest of the fields are planted so that rodents from the surrounding areas are attracted to it. This "trap crop" is fenced with plastic sheeting which has multiple holes through which rodents can pass, and rodents are trapped using multiple-capture traps set along the holes. The plastic fences guide the rodents towards the holes. Field studies in rice cropping systems in Southeast Asia have shown that this method reduces the abundance of rodents over a large area surrounding the “trap crop” [39, 40]. It has been shown in Tanzania that a 20m x 20m cTBS significantly reduces rodent abundance over an area of up to 16 ha of irrigated rice fields, leading to an increase in rice yield by 41% [41]. A simplified variant of cTBS, known as LTBS (Linear Trap Barrier System), has been tested in Asia [40, 42] and a pilot study is currently being conducted in the delta of river Senegal. LTBS comprises a stretch of plastic fencing with a minimum length of 100m that is buried a few cm below ground and 60 -70 cm high above the ground. LTBS is installed to intercept rodent movements into or within crop fields using the thigmotaxis behavior of some rodent species (i.e., based on their natural tendency to move along physical barriers) [40]. Unlike cTBS, LTBS does not require setting up "trap crops" to attract rodents. To the best of our knowledge, such alternative rodent management methods have not been formally tested in West Africa and their impact in terms of food production, health and environmental risk warrants to be quantified. There are also other promising methods, such as the use of improved hermetic grain storage bags (e.g., International Rice Research Institute (IRRI) bags, Purdue Improved Crop Storage (PICS) bags), which provide a better grain storage opportunity to farming communities against rodent and insect damages, limit spoilage and reduce aflatoxin contamination [43-45].

Importantly, some rodent management actions may be efficient to decrease rodent abundances and mitigate their deleterious impacts, but they may antagonize crucial socio-economic aspects. First, for local self-appropriateness to be possible, direct costs of EBRM implementation must be lower than rodent-associated impacts inflicted and this should also be true for the perception that farmers have of their corresponding gains and losses, not only their true monetary values. Second, the timing of the management shall be compatible with the local agricultural calendar in order to facilitate mobilization of working resources. Besides, to ensure greater effectiveness, the management actions be taken when the rodent population is at a low density (i.e., in the lean period before they multiply) rather than during outbreaks when the population is too large to control. Third, one should be very cautious about the inter-relationships between rodent management actions following cropping calendar and cattle breeding systems, especially in the Sahelian region where pastoralism is a widespread and critical activity, whether in terms of food, cultural or saving aspects. For instance, in the Sahelian pastoralist livestock production system, grazing stubble is an important component and, provided that overgrazing is avoided, the practice greatly contributes to soil fertility by adding manure. In such a context, post-harvest actions such as field clearing may be efficient to reduce pest rodent abundances but very detrimental to domestic animals and associated meat, milk and leather production. Some cattle breeders also mentioned the risk of having cattle wounded by pitfall traps (i.e., Kornaka) while wandering at night (K. Hima, pers. obs.). To minimize such risks and potential antagonism from local residents, grazing stubble could be timed and incorporated into other activities of field clearance and pitfall trap may be covered (i.e., closed) during periods of cattle grazing. In brief, the success of EBRM in this region will strongly depend on a fine-tuned balance between socio-economic gains and investments.

## 4. Conclusion

The proper implementation of EBRM entails building on locally adapted communication and awareness raising campaigns in order to mobilize stakeholders (examples of possible media: audio broadcasting [46, 47]; theatre plays, [48] see also [49]; brochures and practical guides [50-52]). To do so, it should be possible to rely on already existing networks (e.g., local/rural radios, farmer cooperatives, community health centers) and interactions with Crop Protection Services or hygiene departments and with other types of agricultural or extension services that are closely linked to farmers. Community synchronization of all the practices should be strongly encouraged. In both rural and urban settings, the priority management targets should include limiting or eliminating potential sources of shelter and food for the rodents and deterring (or excluding) rodents from approaching and accessing any potential resources of shelter and food available in the area. The timing of the implementation of the set of both actions must be determined well in advance with the communities to account for their knowledge, attitude and practice, for instance using Focus Group interviews (Figure 5), and to inflict the maximum impact on the rodent population before the onset of the breeding season and subsequent proliferation of population.

Considering that EBRM is at its infancy stage in sub-Saharan Africa and the current lack of coordination of the small scale trials done in several countries in the continent (see Supplementary

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material, S1 Table), we call for a community of knowledge and practice, with the willingness and skills to work together by combining available experience, resources, and endogenous and scientific knowledge. It is in this context that, based on the Ethiopian initiative, a "Green Rodent Control" network has been formalized recently for sub-Saharan Africa (wee the provisional expert network hit map from the Rodent Green website: www.rodentgreen.com) whose aims are (i) promoting EBRM in Africa, especially through the networking of academics working in the field in the continent, and (ii) the fueling of interventional research programs on EBRM in various African socio-ecosystems.

**Figure 5.** Group meetings between scientists and communities in Niger and Senegal, an essential step in determining people's knowledge, attitudes and practices.

**Supplementary Materials:** S1 Table. A list of work on rodent control in sub-Saharan Africa: recent research programs and selected references specifically focusing on Ecologically-Based Rodent Management. S1 File. French version of manuscript "Rodent proliferation in urban and agricultural settings of sub-Saharan Africa – Part 2. Towards integrated management strategies, and beyond".

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