STRENGTHENING RESEARCH AND INNOVATION (R&I) IN NATURAL RESOURCES MANAGEMENT (NRM) AND WASTE MANAGEMENT (WM) IN MALAWI, MOZAMBIQUE, TANZANIA AND ZAMBIA

CAPACITY BUILDING FOR TRAINING AND RESEARCH INSTITUTIONS ON COMMUNITY-BASED NATURAL RESOURCES MANAGEMENT AND WASTE MANAGEMENT WORKSHOP REPORT

Group photo of Workshop Participants, Mount Meru Hotel, Arusha Tanzania

Prepared by the College of African Wildlife Management (CAWM), United Republic of Tanzania for
The Southern African Development Community (SADC) Secretariat

Activity Contract # SADC1315/1158

March, 2024

OACPS R&I

Acknowledgements

We thank all the 39 participants representing the four SADC Target countries of Malawi, Mozambique, Tanzania and Zambia for squeezing their precious time to prepare themselves and travel to attend this important workshop. Their well fetched presentations allowed for in-depth reflections on the R&I practices existing on the ground on the twin topics of Community-Based Natural Resources Management and Waste Management. Their highly interactive and open discussions were key to the realization of the objectives of the Workshop. We also cordially thank Dr George Wambura of SADC for attending the workshop in person, despite his busy timeline. His shared deep insights on the RINaWa project were extremely valuable in guiding the workshop discussions. The scene setting online presentation by Prof. Gerard den Oeden of OACPS[1] is also highly acknowledged. Lastly, we thank the management of Mount Meru Hotel for their excellent hosting of the Workshop.

[1] Organization for African, Caribbean and Pacific States

Executive Summary

This workshop was carried out as part of the ongoing RiNaWa project, which is currently being piloted in the four target SADC countries of Malawi, Mozambique, Tanzania, and Zambia. The project aims to harness up-to-date Research and Innovation (R&I) for sustainably managing both Waste and Natural Resources within the SADC Region. This workshop was specifically designed to identify and prioritize Waste Management (WM) and Natural Resources Management (NRM) R&I options existing on the ground in the four target countries. Such prioritization could then facilitate their subsequent adoption, adaptation, and domestication or upscaling within the region. The workshop was held from 4-5 January 2024, and attended by 39 participants from 12 Research and tertiary education institutions from all the four target countries. A series of 20 presentations on home-grown R&I options were made by these academicians and researchers, followed by in-depth debate both in the plenary and in the working groups to allow for a deeper exchange of knowledge and practices of the R&I's options thus presented. Using standardized criteria and methodology, the initial list of 47 R&I options was distilled down to 15 for detailed group discussions whereby five (5) of them were finally rated as the topmost suitable for further considerations of adoption or domestication within the region. For NRM these were: (i) Establishment of NRM conservation (ii) Identification of medicinal plants using artificial intelligence (iii) Biogas production (iv) Digital alarm to inform waste collectors (Smart bins) tied with (v) Production of animal feeds using black soldier flies. This prioritization was highly consultative and academically robust, it is considered that the selected R&I priorities reflect the actual choices existing on the ground. It is thus recommended that subsequent steps in exploring R& I options for domestication and upscaling within the SADC region consider these priorities.

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1. BACKGROUND INFORMATION

The majority of rural community areas within the SADC region are rich in wildlife populations, which bear immensely on local livelihood and national economies. These and other wildlife-protected areas in Africa provide a range of ecosystem services. For instance, they help regulate diverse climate change-related impacts - such as droughts, floods, sea level rises, and storms (Lopoukhine et al., 2021; Musa & Kadigi, 2015) or serve as a major source of energy. Berghöfer et al., 2021note, for example, that 40 of 50 Africa's largest hydropower reservoirs are located in protected areas. Wildlife-protected areas are also a prime source for nature-based tourism - which attracts about 88% of Africa's volume of tourists, generating some 10 million tourism-related jobs annually (Berghöfer et al., 2021).

Despite their apparent benefits, wildlife-protected areas continue to confront indiscriminate human-mediated resource harvesting pressures of unprecedented dimensions and heightened scales. Both deforestation (https://www.awf.org/land-habitat-protection) and poaching and Illegal Wildlife Trade (IWT) (Uhm & Moreto, 2018) are commonplace, already pushing some species to the brink of extinction. Desertification, water scarcity, and contamination as well as air pollution are all steadily intensifying, impinging negatively on biodiversity and human livelihood (Crist et al., 2017'; Kumar, 2022a; Mkonda, 2022). This dire scenario has led to a widespread disruption of ecosystem processes and functioning (Crist et al., 2017; Edelblutte et al., 2023). Consequently, Human-Wildlife Conflicts (HWC) on a record high, in part reflecting a common laxity in enforcing land use plans (Suich, 2013; Manral et al., 2016; Njera et al., 2016; Nyhus, 2016; Umar & Kapembwa, 2020; Kuiper et al., 2022; Braczkowski et al., 2023; Edelblutte et al., 2023). Taken together, this gloomy conservation situation puts the future sustainability of wildlife resources hence their inherent potential to support community livelihood at crossroads.

Poor waste management is another environmental challenge, especially in the developing world (Abdel-Shafy and Mansour, 2018). According to the recent Baseline Report (RINaWa, 2023), for instance, solid waste collection from within the four SADC countries of Malawi, Mozambique, Tanzania and Zambia is only about 25-32% of the volume generated per year by any one country. This undesirable scenario partly reflects the inherent weak waste management capacities of these countries including budgetary constraints (Liyala, 2011; Hoornweg and Bhada-Tata 2012). RINaWa (2023) also notes that the academia in these countries is generally ill prepared in terms of curricular for effective training in sustainable Waste Management (WM), and that their institutional synergies, linkages, and even collaborations with other partners towards promoting sustainable WM remains weak as well. Low political will in addressing issues of WM is also a general concern in some countries.

In African countries waste is generated from a multiplicity of domestic, commercial, and industrial sources (Achankeng, 2003; Nyampundu et al. 2020). However, ongoing economic transformations have led to a sharp rise in living standards - especially in urban areas.

Consequently, the urban population is burgeoning in parallel with both the extraction of natural resources and a colossal generation of waste. Today, as urbanization continues to deepen poor waste management is a major topic of environmental and public health concern globally (Adeel and Jun-Li, 2023).

To sustainably manage both natural resources and waste demands for technologically informed decisions (Suratman et al., 2023). Here, the role of research institutions and academia becomes particularly pertinent (Meinzen-Dick et al., 2002). Research may, for instance, help determine how property rights incentivize the adoption of novel technologies or illuminate effective measures for the domestication of technologically driven best practices. On the whole, the application of effective technologies in addressing these twin Natural Resource Management (NRM) and WM challenges should benefit humanity as a whole, including local communities (Kumar, 2022b).

Despite good intentions, the majority of WM and NRM technologies are, however, extremely costly (Berger-Tal and Lahoz-Monfort, 2018). In Africa in particular, this is further compounded by a lack of effective synergies among players, which further frustrates technological transfer, adoption, and domestication (Weisser et al., 2014; Holdsworth et al., 2015; Crick et al., 2018) as well as exchange of R&I expertise and experiences (Domanski et al., 2020; Kegamba et al., 2022). A handful of research and training institutions within the SADC region have generated a couple of R&I options addressing NRM and WM that could be considered for upscaling. However, most such efforts so far remain fragmentary, not shared, or even unnoticed. Consequently, R&I generation, let alone their exchange and upscaling is a major question within the SADC region. This workshop was carried out within the auspices of the SADC RINaWa project to address such a critical gap in information. It specifically sought to address Output 2.1.1 of the Project implementation log-frame 'Capacity building workshop on delivering innovative research and training", for their possible adaptation, adoption and upscaling within the region.

2. OBJECTIVES OF THE WORKSHOP

The main objective of this two-day workshop was to identify and prioritize the best R&I practices spearheaded by the Research and Training Institutions that exist in the four target countries of Malawi, Mozambique, Tanzania and Zambia, that could effectively foster sustainable WM and NRM within the SADC region.

Prof. Jafari Kideghesho, Rector of Mweka College delivering the opening speech for the Workshop

3. WORKSHOP APPROACH

3.1 Plenary Presentations

This workshop was planned to initially gather exhaustive R&I information on WM and NRM that exist within the four Target SADC countries. To start with, 39 Academicians and

A Participant from Zambia delivering the presentation on R&Is from his institution

Dr George Wambura from SADC delivering a background presentation on the RINAWA Project

Researchers from these countries (**Appendix I**) carried out country-specific formal presentations in the plenary on these topics that were also made available online to ensure participation from a wider audience.

Specifically, these presentations sought to identify country-specific R&I WM and NRM practices, for subsequent debate on those most suitable for domestication and uptake within the SADC region. A presentation by Prof. Gerard den Ouden (OACP) was also delivered to help set the scene on the practicalities of the assignment at hand, with a quick reference to the basics of project planning and management, in view of the ongoing RINaWa Project. A total of 20 (15-minute) presentations were delivered altogether in the plenary, of which 6 addressed NRM and 14 WM (**Appendix II**). This rich volume of presentations provoked substantive subsequent debate in view of the R&I prioritization exercise (see section 3.2).

3.2 Break-out Groups

Following the plenary presentations, participants were divided into two breakout groups to discuss and prioritize on case-specific best R&I practices. Discussions were thus guided by the contents of the plenary presentations, together with country-specific home-grown professional knowledge, skills, and experiences. Participants were grouped according to their professional backgrounds (WM; 12 participants and NRM; 27 Participants). R&I information gathered from group work was supplemented by desk reviews.

Participants discussing during a group break-out Session

3.3 Methodology for Prioritization of R&I Practices

During the group break-outs, participants were encouraged to discuss exhaustively and reach consensus on the priority NRM and WM R&I options existing within the region. Each R&I option proposed was first identified as a *Product, Service, Process* or *Technology* and then assessed based on a set of five (5) criteria: *Technological credibility, cost effectiveness, Sustainability, Scalability*, and *Acceptability* (**Table 3.1**). Following in-depth discussions, each candidate R&I practice was then separately assigned a 'preference' score of 1-3 (L=Low, 2=Medium, 3=High) by each participant. The Average weighted scores were then computed for each of the R&I option assessed.

Table 3.1: Categories, criteria and ranking of R&I options for prioritization

Category	Criteria	Priority Ranking (Score)
Product	Technological credibility	Low (1)
Service	Cost effective	Medium (2)
Process	Sustainability	High (3)
Technology	Scalability	
	Acceptability (Socio-political)	

4 FINDINGS ON PRIORITIZED R&I PRACTICES

The 20 plenary presentations (6 on NRM and 14 on WM - see **Appendix II**) yielded a total of 47 individual R&I options considered worth discussing by the participants (**Appendix III)**. A selection of 16 of these, comprising of four per country (two each from WM and NRM thematic areas; total = 16 options) were thus subjected to further intensive debate through group discussions to allow for eventual prioritizations (see section 3.3). The results of this prioritization are presented in **Table 4.1**.

Table 4.1: Prioritized R&I following Group discussions

(a) NRM

Existing R& I Identified	Category	Score	Rank	Country
Establishment of CBNRM conservation	Service	15	1	Malawi
Identification of medicinal plants using artificial intelligence	Technology	12	2	Zambia
Use of SMART technology for biodiversity monitoring and research	Technology	11	3	Tanzania
Habitat rehabilitation	Service	11	3	Malawi
Identification and mapping of ecosystem services	Process	11	3	Mozambiqu
SMART early warning system for Human-Wildlife Conflicts	Technology	10	4	Zambia
Microbial pesticide for protection of crops (bio-pesticide)	Product	9	5	Tanzania
Harmonization of CBNRM governance	Process	9	5	Mozambiqu

(b) WM

Existing R&I	Brief description	Category	Score	Rank	Country
Biogas production		Product	14	1	Malawi
Digital alarm to inform waste collectors when waste bin is full		Technology	13	2	Malawi
Production of animal feed using black soldier flies		Products	13	2	Tanzania
Production of animal feed using black soldier flies		Product	13	2	Zambia
Production of Biofertilizer from waste		Product	12	3	Mozambique
Implementation of extended producer retention (EPR)		Service	12	3	Zambia
Fuel production using plastic waste		Process	11	4	Mozambique
Bio-briquettes production from waste		Product	11	4	Tanzania

These results indicate that for NRM, the participants reconciled that the process or system of establishment of CBNRM conservation (Malawi), and the identification of medicinal plants using AI

technology currently (Zambia) are two NRM R&I priorities worth taking forward. In the case of WM, Biogas production technology (Malawi), The use of digital alarm to alert waste collectors of waste due for collection (Malawi) and Production of animal feed using black soldier flies (Tanzania and Zambia) were the three topmost prioritized options.

Since the identification these R&I options were subjected to a rigorous debate and analysis through presentations and subsequent round-table in-depth discussions, it may be safely taken that these are the five topmost R&I options that currently exist on the ground. Therefore, they may be considered the most R&I options immediately available for consideration of uptake through the RINaWa project, based on the workings of this workshop. However, it is clear that this workshop generated a much broader wealth of R&I options (47 in total) than those prioritized here. Further scrutiny of additional R&I options from the list thus generated, based on wider criteria may better inform subsequent prioritizations depending on specific circumstances and requirements.

5 LITERATURE REVIEW ON R&I BEST PRACTICES OPTIONS

A desk review of R&I best practices was also done so as to complement information thus gathered in the workshop. This information is presented here so as to broaden the scope of existing options beyond those identified within the workshop by Target country experts.

5.1 Reviewed R&I in NRM

The NRM R&I options documented in literature focus mainly at addressing contemporary NRM challenges, including Human-Wildlife Conflicts (HWCs), Poaching and Illegal Wildlife Trade, Habitat restoration, Wildlife corridors and enhancing Community-Based Natural Resources Conservation. These are summarized in **Table 5.1**.

Table 5.1 R&I options for addressing NRM challenges (sourced from literature; * items not specifically mentioned during the workshop session) (Lichtenfeld et al., 2015; Kissui et al., 2019; Hermanstorfer, 2023; Moyo and Epulani,2002; Njera et al., 2016; and De Aquino, 2018)

	R& I Option
	Mitigation of Human-Wildlife Conflicts
1	Use of fortified chain-link boma
2	Guardian dogs
3	Movement Activated Guard (MAG) Systems
4	Electronic Training Collars
5	Artificial sting-bee pheromones*
6	Recorded sirens
7	Fire crackers

8 Electric shock collars
9 Foul testing chemicals*
10 Early warning geo-referencing*
11 Use of sound-emitting drones*
12 Use of Chili fences and bricks
13 Beehive fencing
14 Electric fencing in hard edge areas*
15 Cultivation of unpalatable crops (Okra, Sesame, Sunflower, Lemon, Ginger and Chili)*

Combating Poaching and Illegal Wildlife Trade (IWT)

16 Using SMART technologies to strengthen law enforcement
17 Engaging community-based Informers*
18 Involving Community-based Game Scouts
19 Strengthen Information sharing processes
20 Physical removal of invasives plants
21 Use invasives for charcoal production
22 Construction of artificial ware dams
23 Development of weirs along seasons rivers

Restoration of Wildlife Corridors

24 Preparation and use of land-use plans

Enhancement of Community-based Natural Resources Management

25 Provision of economic benefits to the communities
26 Improving conditions of natural resources
27 Devolved authority over resources
28 Consideration on local community rights and tenure
29 Effective institutional framework
30 Co-management or 'take and give' relationships
31 Provision of supportive policies
32 Equitable and inclusive stakeholder engagement

5.2 Reviewed R&I in WM

Several WM R&I options available for addressing WM Challenges have also been identified in literature. These are presented in **Table 5.2**.

Table 5.2 R&I options for addressing WM challenges (sourced from literature; * items not specifically mentioned during the workshop session) (Achankeng, 2003; Environmental Council of Zambia, 2004; Hristovsk et al. 2007; URT 2021; Hristovsk et al. 2007; Hoornweg and Bhada-Tata 2012.)

	R&I Option
1	Effective engagement of local communities
2	Reuse, Recycle and Recovery of waste
3	Waste water treatment (stabilization ponds and oxidation ditches)
4	Planned housing and settlements
5	Sustainable financing of WM*
6	Engagement of the private sector and NGOs*
7	Adoption of appropriate policies
8	Enforcement of local by-laws and regulations

Overall, it is clear that most of the R&I options identified in literature are also being practiced in the Target countries. However, some R&Is mentioned in literature as practiced elsewhere, [marked with asterisks (*)] are considered additional avenues that can be explored further in the course of refining the available R&I priorities for the SADC region.

6 R&I OPTIONS INDENTIFIED DURING BASELINE SURVEY

The R&I Options identified through both this workshop (Section 4) and Literature Review (Section 5) were collated with those identified earlier during a Baseline Survey (Table 6.1). With the exception of (i) The use of live owl to control pests (rodents & other birds) and (ii) Use of Robots in agricultural irrigation (Climate smart agriculture) in NRM, almost all other options listed during the Baseline survey were also mentioned during this workshop or identified through literature survey. These options may therefore be considered together with the results if this workshop. However, combining all the three results, it can be safely deduced that the list generated so far of R&I WM and NRM is reasonably exhaustive for further considerations within the workings of this project.

Table 6.1: R& I Options identified during Baseline Survey (RINaWa, 2023)

(a) NRM

	R& I Option
	Mitigation of Human-Wildlife Conflicts
1	Beekeeping for api-tourism

2	Human-wildlife conflicts toolkit and SAGE
	Enhancement of Community-based Natural Resources Management
3	Clean water for forest adjacent protected areas
4	Rabbit urine for biopesticides
5	Amphibian sampling and CBNRM best practices
6	Composting and recycling for agricultural nutrients and for generation of energy (biogas).
7	Use of waste biomass in farms to enrich soils (including human waste)
8	Agro-processing i.e., waste as applies to food processing, routine waste management
9	The use of live owl to control pests (rodents, other birds)*
10	The use of robot machine in agricultural irrigation (Climate smart agriculture)*
11	Honey Production
	Combating Poaching and Illegal Wildlife Trade (IWT)
12	Camera traps to detect potential poaching activities in rea

(b) WM

	R&I Option
1	Biogas production
2	Waste recycling through circular economy
3	Making of briquettes from agriculture, forest waste, charcoal dust and faecal sludge
4	Making of compost and resource recovery
5	Biotechnology
6	Sanitation mapping
7	Waste pickers digitization
8	Production and packaging of methane
9	Designing of septic tanks does not get full
10	Recycling of solid wastes (bottles-plastics)
11	Developing management systems for liquid and solid wastes
12	Bricks and aggregates from solid waste*
13	Maggots (soldier flies) production from kitchen waste
14	Bioelectricity from waste water and fecal sludge
15	Biopesticide using tobacco and other agricultural products
16	Carbon dioxide capture and utilization
17	Dewatering fecal sludge treatment
18	Waste water irrigation system
19	Smart Waste Management
20	Biogas production and bio digester (utilizing the sludge as manure).

21	Liquid waste stabilizing system
22	Using Remoting sensing GIS satellite image to know the state of waste in a certain area

7. CONCLUSIONS AND RECOMMENDATIONS

The 20 country-specific presentations and the subsequent guided group discussions led to the identification of five NRM and WM R&I options considered priorities within the workings of this workshop. Further options were generated through literature review and the results of the Baseline Survey for the project. Since the workshop process was inclusive, highly consultative and guided by in-depth professional discussions, this prioritization is considered a fair representation of the actual R&I situation on the ground. It is therefore recommended that the five R&I prioritized options: (i) Establishment of CBNRM conservation, (ii) Identification of medicinal plants using artificial intelligence and (iii) Biogas production (iv) Digital alarm to inform waste collectors for WM be and (v) Production of animal feeds using black soldier flies considered for uptake and upscaling within the SADC region.

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APPENDICES

Appendix I: List of participants

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Appendix II: List of presentations

	Name	Institution	Country	Title of Presentation
1	Junice Dzonzi	Lilongwe University of Agriculture and Natural Resources	Malawi	Exploring Practical Options for Sustainable Management of Protected Forests in Malawi: *Insights from Dzalanyama Forest Reserve*
2	Chikumbusko Chiziwa Kaonga	Malawi University of Business & Applied Sciences (Mubas)	Malawi	Alternative fuel production from waste
3	Principal Mdolo	Lilongwe University of Agriculture and Natural Resources	Malawi	Sustainable WM using Anaerobic Digestion
4	Dr John Taulo	Malawi University of Science and Technology	Malawi	Waste-to-Energy: A pathway from renewable energy sources to sustainable development in Malawi
5	Monica F. Kalagho Gondwe	Malawi College of Forestry and Wildlife	Malawi	Maximizing Sustainability & Conservation Efforts
6	CHRIS KAMBANI-BANDA	Lilongwe University of Agriculture and Natural Resources	Malawi	LUANAR Waste Management Strategy
7	Dr Hugo Mabilana	Oceanographic Institute of Mozambique	Mozambique	Addressing Waste Management in PSEPA: Plastic Pollution
8	Prof Saidelamine Abibe Mahadal	Rovuma University	Mozambique	Sanitization And Increase Of Nutrients In Anaerobic Sludge With The Addition Of Plant Biomass Ash For Agricultural Use.
9	Artur Afonso	ReGeCom	Mozambique	Building a CBNM through National Platform In Mozambique
10	Baadru Hagy	Rovuma University	Mozambique	Research & Innovation in Natural Resources Management: the case of UEM DCB Mozambique
11	Eduardo Bata	Rovuma University	Mozambique	Natural Capital & Governance: Tasks in Natural Resource Management

	Name	Institution	Country	Title of Presentation
12	Dr Angela Gerald Mkindi	The Nelson Mandela African Institution of Science and Technology	Tanzania	The Nature-based approach for managing and restoring invaded ecosystem
13	Dr Never Mwambela Zekeya	College of African Wildlife Management	Tanzania	Microbial biopesticide
14	Dr Shadrack M. Sabai	Ardhi University	Tanzania	Waste Management Resource Recovery
15	Maria J. Millinga	College of African Wildlife Management	Tanzania	Waste management Tanzania
16	Alice Chilambwe	Copperbelt University School of Natural Resources	Zambia	
17	Mitulo Silengo	School of agriculture & natural resources, Mulungushi university, Kabwe, Zambia	Zambia	Climate Change and Adaptive Land Management
18	Brian Halubanza	Mulungushi University-	Zambia	Artificial Intelligence (AI) and Internet of Things
19	Garikai Membele and Progress H. Nyanga	University of Zambia	Zambia	Solid Waste Management in Zambia
20	Alick Mwansa Makasa	Zambia Environmental Management Agency	Zambia	Waste management

Appendix III: List of R&I practices identified from the presentations

	R&I Option
1	Spatial Monitoring and Reporting Tool - (SMART) for collection of field data in protected areas for biodiversity conservation
2	Digitalization of Herbarium collections to enhance learning and research
3	Anti-poaching alert system using SMART technology
4	Identification of medicinal plants using Artificial Intelligence (AI)
5	Birds' identification systems using AI
6	Habitat condition monitoring
7	Identification of locust invasion using AI
8	Use of AI to interpret photo images from aerial wildlife sensors
9	Aerial multi-species detection using TK7 sensor (LWIR and RGB images).
10	University curriculum review to accommodate new issues in NRM
11	Afforestation
12	Farmers Field Schools
13	Treatments of seeds to enhance germination
14	Wildlife monitoring and tracking through camera, telemetry, drones
15	Review of forest regulations
16	Blended endowments and revolving conservation trust financing
17	Digital sensors to alert incoming elephants (using infrared)
18	Ecosystem restoration using biological control/nature-based approaches
19	Use of camera traps based on dedicated protocols
20	Habitat management and research monitoring

	R&I Option
21	Use of quantitative tools in managing PAs
22	Microbial pesticides for protection of crops (*Vuruga* pesticide)
23	VB Liquid insecticide for vector control in humans and animals
24	VB Gel insecticide for vector control including mosquitoes in humans
25	Anaerobic digestion (using biogas on locally made cooking stove), improve soil fertility
26	Policy and Act on Environmental Management to accommodate the WM issues
27	Use waste plastic bottles for sustainable irrigation
28	Rice husks/maize cobs gasification system as an alternative source of electricity generation
29	Biogas production from market waste
30	Purifying and parking biogas into portable cylinders
31	Digital alarm to inform waste collectors when wastebin is full
32	Use of solid waste for making art materials or fuels
33	Use of ash to treat sludge instead of using expensive commercial chemicals
34	Promote the implementation of small fuel production plants through pyrolysis
35	Use of solid waste to enhance soil fertility
36	Use of black soldier flies to turn SW (sisal wastes) into animal feeds
37	Using Bio-slurry for composite making (soil fertilization)
38	Biogas production (making briquettes), and conservation of degraded land.
39	Use of sisal wastes for production of fertilizer

	R&I Option
40	Eco-friendly methods for processing leather
41	Plastic waste shredding for recycling
42	Use of domestic wastes to produce maggots for animal feeds
43	Use of wastes including charcoal dust, animal dung, cashew nut shell, rice husks, fecal sludge etc. for briquettes production
44	Production of bricks from rice husks and clay at 25 to 75 ratio
45	Use of wastes including kitchen leftovers, fruits etc. for compost production
46	Production of decoration paper from waste papers and water hyacines
47	Production of building blocks from wastes in construction sites