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Research Application Summary

Dissemination and adoption of climate-smart farming systems: A case of elite pasture production, agro-forestry and water management schemes in Uganda

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Abstract

The Ugandan cattle corridor is not only a host to the oorest rural households characterized by severe livelihood challenges but also defined by poor soils, semi-arid to dry sub-humid climatic conditions with poorly distributed rainfall. Such a tragic state of affairs if persistent will not make it impossible to economically empower rangeland inhabitants to progress to middle-income status as defined in the NDPII and Vision 2040. The beef sub-sector in the rangeland ecologies has been made more vulnerable due to local cattle breeds with poor genetic potential, rudimentary rearing practices, degraded pasture lands, weak market actors, water scarcity, poor feeding practices, and feed conservation agenda. AGRENES (https://agrenes.org/) and NARO-NaLIRRI (https://nalirri.or.ug/) executed an EU-funded project: 'Improving competitiveness and productivity of the beef sub-sector through fostering gender-responsive, inclusive and sustainable rangeland, agroforestry and water resources (RAWM-RAWM)'. The main aim of the MOBIP-RAWM project was to build the capacity of farmers, district and sub-county actors in the sustainable pasture, agro-forestry, and integrated water management systems. Vibrant, local multi-disciplinary teams were formed to oversee routine establishmet, operations, manage and maintain the new water facilities, infrastructures, agro-forestry and forage nurseries and gardens. Farmers and district actors were supported with elite forage species, conserved feed, hay-making machinery and equipment with the community-owned commercialized spare parts, maintenance and repair services attached in a cost-sharing arrangement. . The complementarity of diversified agro-inputs, seedlings and support products and services regarding agro-forestry with multi-purpose trees as tree cover, fodder, medicinal, firewood, and fruit trees and energy saving sources increased adoption in several communities across the entire cattle corridor. The Domains of Change for the MOBIP-RAWMN action included: i) building or strengthening the capacity of beef farmers, stakeholders, value-cahin actors and end-users, including the district actors and private sector; ii) consideration of gender inclusivity, transformative interventions targeting the most disadvantaged women and youth groups; iii) changes in policies, budgeting and investment priorities at farm level, district and sub-county local governments and society structures to favour mainstreaming, scaling and spillover effects of the project interventions.

Key words: Beef production, Integrated Water Management, Agro-Forestry

Résumé

Le couloir du bétail ougandais est non seulement l'hôte des ménages ruraux les plus pauvres caractérisés par de graves problèmes de moyens de subsistance, mais également défini par des sols pauvres, des conditions climatiques semi-arides à sèches subhumides avec des précipitations mal réparties. Une telle situation tragique, si elle persiste, ne rendra pas impossible l'autonomisation économique des habitants des terres de parcours pour qu'ils accèdent au statut de revenu intermédiaire tel que défini dans le NDPII et la Vision 2040. Le sous-secteur de la viande bovine dans les écologies des terres de parcours a été rendu plus vulnérable en raison de des races bovines locales à faible potentiel génétique, des pratiques d'élevage rudimentaires, des pâturages dégradés, des acteurs du marché faibles, une pénurie d'eau, de mauvaises pratiques d'alimentation et un programme de conservation des aliments pour animaux. AGRENES (https://agrenes.org/) et NARO-NaLIRRI (https://nalirri.or.ug/) ont exécuté un projet financé par l'UE : « Améliorer la compétitivité et la productivité du sous-secteur de la viande bovine en , parcours inclusifs et durables, agroforesterie et ressources en eau (RAWM-RAWM) ». L'objectif principal du projet MOBIP-RAWM était de renforcer les capacités des agriculteurs, des acteurs du district et du sous-comté dans les systèmes durables de pâturage, d'agroforesterie et de gestion intégrée de l'eau. Des équipes multidisciplinaires locales dynamiques ont été formées pour superviser l'établissement de routine, les opérations, gérer et entretenir les nouvelles installations d'eau, les infrastructures, l'agroforesterie et les pépinières fourragères et les jardins. Les agriculteurs et les acteurs du district ont été soutenus avec des espèces fourragères d'élite, des aliments conservés, des machines et du matériel de fenaison avec les pièces de rechange commercialisées appartenant à la communauté, des services d'entretien et de réparation attachés dans un accord de partage des coûts. La complémentarité des intrants agricoles diversifiés, des semis et des produits et services de soutien concernant l'agroforesterie avec des arbres à usages multiples comme couvert arboré, fourrage, médicinal, bois de chauffage, arbres fruitiers et sources d'économie d'énergie a augmenté l'adoption dans plusieurs communautés à travers l'ensemble du corridor du bétail. Les domaines de changement pour l'action MOBIP-RAWMN comprenaient : i) le renforcement ou le renforcement des capacités des éleveurs de bovins, des parties prenantes, des acteurs de la chaîne de valeur et des utilisateurs finaux, y compris les acteurs du district et le secteur privé ; ii) prise en compte de l'inclusion du genre, interventions transformatrices ciblant les groupes de femmes et de jeunes les plus défavorisés ; iii) des changements dans les politiques, la budgétisation et les priorités d'investissement au niveau des exploitations, des administrations locales des districts et des sous-comtés et des structures de la société pour favoriser l'intégration, l'échelle et les retombées des interventions du projet.

Mots clés : Production bovine, Gestion intégrée de l'eau, Agro-foresterie

Introduction

The beef-meat sector in Uganda is challenged by scarcity and inefficient utilization of water resources (Zziwa *et al*., 2012a); low livestock and pasture productivity (Zziwa *et al*., 2012b ; Byenkya *et al*., 2014), and degraded rangelands and agroforestry (MWE, 2016). As a result, beef production in 2013-2014 is 200,000 metric tons but has the potential to grow to 360,000 metric tons (NAPA, 2018). As a result, the livestock farmers have resorted to: i) migration in search for pasture and water; ii) over-stocking and over-grazing; and iii) some are forced to sell their animals

during the frequent, prolonged dry spells (Zziwa *et al*., 2015; Mpairwe *et al*., 2015). However, farmers' responses do not inadequately address the aforesaid challenges.

In response, the National Livestock Resources Research Institute (NaLIRRI) is implementing a component titled: Rangelands, Agro-forestry and Water Resources Management (RAWM) component, under a broader EU-funded project dubbed: 'Market-Oriented Beef Improvement Project (MOBIP) being coordinated and supervised in the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF). The MOBIP-RAWM was a beef improvement project that aimed to promote beef production in Uganda. This project was implemented in nine districts within Uganda's cattle corridor clustered into two distinct Disease Control Zones (DCZ), namely DCZ 1 consisting of Nakaseke, Nakasongola, Masindi, Kyankwanzi and Kiboga districts; and DCZ2 consisting of Mbarara, Isingiro, Kiruhura and Sembabule districts.

The overall objective of the MOIP-RAWM project was to enhance beef production through improved management and reduced degradation of the pasture and water resources in the rangelands of Uganda. The five specific objectives of the study were to: promote gender-responsive and inclusive climate-smart forage production technologies, innovations and management practices; develop the capacity of beef producers and district actors in sustainable and integrated water resources management; promote agroforestry and rehabilitation of degraded rangeland habitats and watershed areas; develop the capacity of stakeholders in sustainable exploitation of synergies in crop-livestock integration; develop mechanisms for monitoring and weather-related risk management.

Justification of the interventions. In Uganda, beef cattle production systems are the most predominant in the cattle corridor, where they are majorly rain-fed, with pastoral and agro-pastoral systems accounting for more than 90% of the total cattle numbers (FAO, 2017). About 44% of the total land area in Uganda is covered by rangelands (Byakagaba *et al*., 2018; NEMA, 2015); and supports more than 90% of the ruminant population (UBOS and MAAIF, 2010). The semi-arid environments of these rangelands are often characteristic of erratic rainfall regimes, high temperatures, frequent and long droughts. Therefore, climate change remains the single major threat to the realization of increased livestock production because of its impact on the quantity and quality of feed crops and forages, water availability, proliferation of livestock diseases, animal reproduction, and biodiversity (Rojas-Downing *et al*., 2017; Kiggundu *et al*., 2018).

Climate change, coupled with overgrazing, have culminated in inadequate and poor-quality pastures and declining water resources in the rangelands dwindling their potential to support the current and projected demands for beef products. In fact, access to safe water resources in the rural rangeland areas was estimated at less than 60% in 2016, and this needs to be greatly improved for enhanced livestock productivity. The trends in the establishment of safe water points inform of boreholes, valley dams and natural springs as whereas their functionality for the rural poor has reduced to 85%, thus threatening livestock productivity.

Most rural households, especially those headed by women, are heavily dependent on wood biomass as a cheaper and affordable alternative to electricity and gas. This has resulted in massive encroachment and unsustainable exploitation of tree and rangeland resources through bush and charcoal burning activities. Therefore, sustainable management of forest cover and rangeland

resources has the potential of reducing negative impacts of climate change, especially greenhouse gas (GHG) emissions. In addition, there is a widening gender gap in Uganda's agricultural sector, including the beef sub-sector that often favours men rather than women in the ownership, access to and control of production resources.

To address the aforementioned challenges, AGRENES under the EU-funded MOBIP-RAWM project facilitated dissemination and promoted the adoption of novel agricultural technologies and climate-smart farming systems, which enhanced beef productivity and restoration of the degraded rangeland ecosystem in Uganda. In this case, the key result areas were; sustainable agroforestry, pasture production schemes and integrated water management systems.

Project intervetion. To streamline implementation of the MOBIP-RAWM project and fast-track achievement of the project objectives, five result areas and work packages were delivered, namely:
(i) Work package 1: Promote interventions for sustainable pasture, agroforestry and integrated water management;
(ii) Work package 2: Facilitate rangeland rehabilitation through shrub/bush encroachment and pasture re-seeding;
(iii) Work package 3: Support the integration of crop in livestock production systems;
(iv) Work package 4: Facilitate enterprise development in agribusiness
(v) Work package 5: Develop mechanisms for monitoring and weather-related risk management.

AGRENES, as one of the Project Implementing Partners, lead the execution and delivery of the 1st and 2nd work packages and result areas, namely; i) promote climate-smart interventions for sustainable pasture production, agroforestry and integrated water management schemes; and ii) facilitate rangeland rehabilitation through bush clearing and pasture re-seeding. Table 1 presents a summary of the project activities implemented by AGRENES.

Table1. A summary of the key activities implemented by AGRENES

S/N	Result Area	Main Activities Implemented
1	Agroforestry	Training of Trainers (ToTs) and farmers in tree nursery production Establishment of tree nurseries/ demos Distribution of tree seedling to the trained farmers for planting in rangelands, on-farm/in agroforestry
2	Integrated Water Management	Planting of tree seedlings and maintenance of agroforestry gardens/ farms Construction of valley dams/ water infrastructures Maintenance of water the established infrastructures
3	Production of forage guides and pasture albums	Professional designing of forage /pasture albums Translation and mass production of agronomic guides
4	Pasture establishment and rehabilitation of degraded rangeland ecosystems	Land preparation and establishment of new pasture gardens Rehabilitation of the degraded pastures/rangelands Re-seeding and agronomy-related activities Training of farmers in pasture production and rangeland management

Materials and Methods

Pre-intervention activities. The MOBIP-RAWM project was implemented by four institutions, namely, the AGRENES, FAO, NaLIRRI and CURAD, hereafter called the Project Implementing Partners (PIPs). In a bid to maximize synergies between the MOBIP-RAWM implementing consortium and the various stakeholders in the beef sector, the consortium first established contacts with the beef farmers using the formal local government structures at the district and sub-county levels in the nine districts within the cattle corridor (also called the DCZ 1 and 2).

Initially, 'Needs finding' and scoping studies were conducted to collect baseline information. The baseline information was gathered using the existing local government structure in the nine selected districts. The consortium established) in each of the nine target districts. The DFPPs introduced the consortium into their respective livestock farmers and beef producer communities (Table 2). The data was used to establish the project benchmarks and baseline metrics.

Key informant interviews (KII) were conducted with the district staff, including the farmers, livestock keepers (preferably beef producers), District Agricultural Officers (DAO), District Production Officers (DPO), the District Veterinary Officers (DVO), political leadership, and where applicable the cultural leaders of the target districts and sub-counties. The concerns/ challenges raised from the interviews were prioritized in order of importance. Following the key informant interviews, the consortium also conducted focus group discussions (FGDs) with farmers and beef producer groups. Information from these engagements was captured using a participatory learning approach.

Table 2. The District Focal Point Persons (DFPPs) for the MOBIP-RAWM project

S/N	District	Name	Title	Telephones	Email Address
1	Kiruhura	Twinamasiko Robert	Mr	0783 447699	roberttwina@yahoo.com
2	Mbarara	Akashaba Andrew	Dr (Acting DVO)	0782 710354	akashabaandrew8@gmail.com
3	Isingiro	Kasozi Bruhan	Dr – DVO	0752 598184	brukasozi@gmail.com
4	Sembabule	Ssali Angelo	Dr-DVO	0772 384959	Ssali.angello@gmail.com
5	Masindi	Isingoma Didan	Mr	776011020	isingomadidan@gmail.com
6	Nakaseke	Kalanzi Stephen	Dr.	0775596561	stephenkalanzi90@gmail.com
7	Kiboga	Tingira John Bosco	Dr	0772428394	hortonie2000@gmail.com
8	Nakasongola	Kiwanuka Enoch Kem	Mr	0782465814	enochkem@gmsil.com
9	Kyankwanzi	Kabuugo Thomas	Dr	0782438660	thomkvet@gmail.com

Selection of the MOBIP-RAWM project beneficiaries. The baseline data from the needs finding studies and KII coupled with contextual analyses facilitated by the designated DFPPs (Table 2) informed the selection of the MOBIP-RAWM project final beneficiary sub-counties, beef farmers and farmers groups in the nine districts. A stratified purposive sampling procedure (Palinkas *et al*., 2015); was employed in the selection of the final beneficiary framers and farmer groups within each select sub-countries, parishes and village. Besides the gender considerations, only farmers and farmers groups who were willing to offer part of their farmland for the establishment of the water infrastructures, pasture gardens, and agroforestry systems were prioritized and selected as the final beneficiaries.

AGRENES engaged both the district local governments and the DFPPs in the following ways: i) they guided, informed and sometimes led the processes of selecting the project sites; ii) they selected or recommended for selection of the local government staffs to be trained as ToTs in sustainable pasture production and water management; iii) DFPPs are directly engaged and involved in monitoring or evaluating the performance of field activities and provide technical backstopping, and iv) they also participate in project review meetings at the field level. The DFPPs are the channels through which the project interventions and reports reach the district and sub-county councils. The reports contain pertinent project results and recommendations of the best practices in climate-smart agroforestry and integrated water management systems, as well as contextually-relevant technologies in pasture establishment and rehabilitation of the degraded ecosystems.

Study area and location of beneficiaries. Over 600 individuals benefited from the AGRENES MOBIP-RAWM project interventions. In each of the nine target districts within the cattle corridor, the sub-counties and parishes with highly degraded rangeland ecosystems and are most vulnerable to climate change impacts, water scarcity and environmental degradation were selected. Final beneficiaries were chosen from different villages in each parish and sub-county.

Figure 1 shows the schematic representation of the locations of the beneficiary farmers in the target districts, as well as the parishes, sub-counties and villages receiving the AGRENES MOBIP-RAWM intervention packages.

The baseline data and indicators for the MOBIP-RAWM project. Table 3 shows the MOBIP-RAWM project baseline metrics and benchmarks and their output indicators. The baseline metrics form the reference Monitoring and Evaluation (M&E) tool, against which the project performance was gauged. The M&E tool was deployed in assessing technical progress, success and failures (if any) during and after execution of work packages.

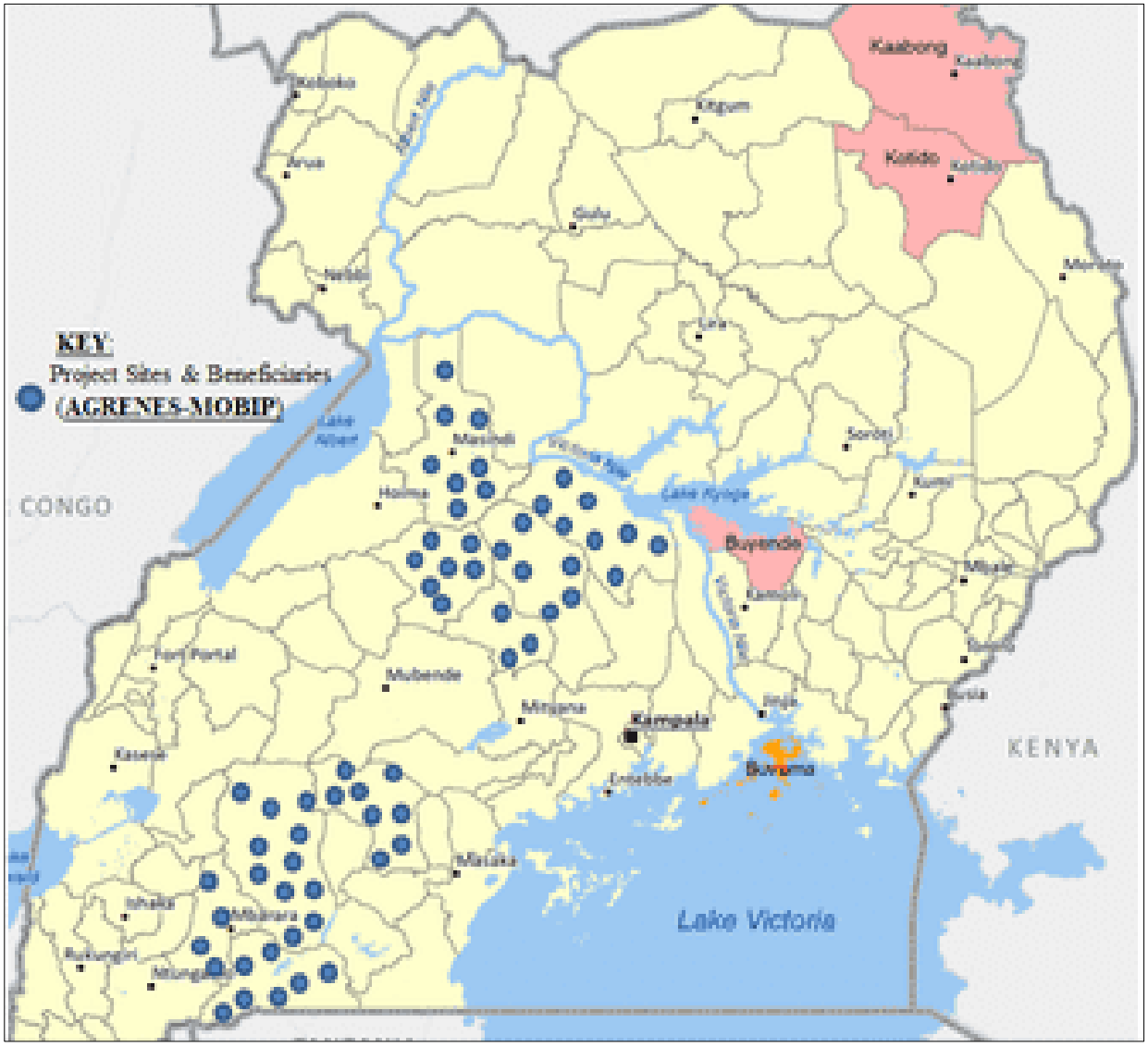

Figure 1. Schematic representation of the locations of the beneficiary farmers in the nine target districts for the AGRENES MOBIP-RAWM project, Uganda

Table 3. The baseline data and output indicators for the MOBIP-RAWM project

	Results chain for the MOBIP-RAWM	Indicator of the MOBIP-RAWM project	Baseline (Base year 2019)	Target by 2021 (reference year)	Current value
Impact	Level of aggregate beef production in the target districts (DCZ 1 and 2)	Quantity of beef produced in DCZ 1&2in metric tons (MT)	78,000 MT	90,000MT	78,000
	Incomes from beef increased		4,000/= at farm gate and	6,000/= by both primary producers and fresh meat vendors	
		Profit mark-ups received by meat supply chain actors	fresh meat butcheries		4.000/=
Outcomes	Beef meat productivity and quality enhanced	Time is taken to market weight	Mature weight 250 – 300 Kg in 5 years	Mature weight 250 –300 Kg in 2 years	250-300 Kg
	Beef meat quality enhanced	Prop. of meat to bone ratio	50 %	70 %	50 %
	The capacity of district actors and beef producers in climate-smart forage production and sustainable rangeland management enhanced	No. of district actors, beef and forage farmers skilled and promoting sustainable range management practices	Nil (for district actors)	- Over 54 (district actors) -Over 27 (forage producers)	Nil (for district actors)
			Nil (forage producers)	- 450 acres of new & rehabilitated	Nil (forage producers)
Results and Outputs	2. Capacity in sustainable water harvesting and management of resources enhanced	-No. of rehabilitated or newly constructed water facilities.	Nil	18 infrastructures	Nil
		-No. of district actors skilled in sustainable water harvesting and management of resource	10 %	50 %	10 %

3. Production of multipurpose trees/shrubs in degraded rangeland habitats and watershed areas promoted	-No. of farmers supplied with the multipurpose tree and shrubs seedlings -No. of farmers skilled in the management of trees/shrubs in agroforestry -No. of farmers trained in utilization and integrated agroforestry systems	Nil Nil	1000 farmers supplied with 400 seedlings each About 44,000 tree seedlings per district 1500	Nil Nil
5. Weather Index-Based Insurance for Beef Producers developed	No. of packages developed to suit beef production activity profiles in DCZ 1&2	Nil	3	Nil

Results and uptake pathways

Establishment of new pasture gardens and rehabilitation of the degraded pasture and rangeland ecosystems. Climate change has adversely affected beef production in the cattle corridor, and the local climate is characterized by extreme weather episodes such as drought, dry spells and erratic precipitation and is now becoming more frequent and intense (Nalukwago *et al.,* 2019: Susan *et al.,* 2020). As such, the cattle corridor, mainly the nine project districts, face an unprecedented degradation of pasture lands and supportive rangeland ecosystems. In response, new pasture gardens were established and the degraded rangeland ecosystems rehabilitated to increase availability, supply and last-mile access to quality forages and feed resources for enhancing beef productivity in the target farming communities.

Conservational climate-smart farming practices such as bush clearing, sowing of the forage seeds, re-seeding, over-sowing and harvesting were deployed during the establishment of new pasture gardens and rehabilitation of the degraded rangeland ecosystems. Two elite forage varieties of *Chloris gayana* (Rhodes grass) and *Centrosema pubescens* were used in opening-up pasture gardens and rehabilitation of the degraded rangeland ecosystems. The elite varieties of *Chloris gayana* and *Centrosema pubescens* were selected because they are high-yielding and with drought-tolerance traits. These traits make Chloris gayana and Centrosema varieties capable of withstanding abiotic stress and flourishing better than the traditional forage varieties even under dry spells and other harsh weather conditions.

Establishment of new gardens with improved and drought-tolerant pastures. A total of 483 acres of new pasture gardens were established on 37 private beef farms across the cattle corridor in the nine target districts under the MOBIP-RAWM project. On average, 13 acres (5.2 ha) of *Chloris gayana* and *Centrosema pubescens* gardens were established on each beef farm. The process of creating seedbeds for the new seed pasture gardens involved five steps, namely site selection, bush clearing to remove shrubs, levelling of the seedbed, manual and mechanical ploughing, and harrowing of the seedbeds. The established pasture gardens were maintained by re-seeding and seasonal weeding cycles. Figure 2 shows sample field photos taken during sowing of *Chloris gayana* pastures at a beneficiary beef farm in Nakasongola district.

Figure 2. Sample field photos taken during sowing of Chloris gayana pastures at a beneficiary beef farm in Nakasongola district, Uganda

The pasture seedbed planted with Chloris gayana across the nine districts was intercropped with improved forage legumes and Centrosema pubescens. Standard agronomic protocols for mixed cropping and cultivation of Chloris gayana and Centrosema pubescens (AGRENES, 2020a and b); were followed during the establishment of the new pasture gardens.

Figure 4 shows photos of the newly established and functional pasture gardens at one of the MOBIP-RAWM project sites in the Nakasongola district.

Figure 3. Sample field photos for fully established new pasture gardens under the MOBIP-RAWM project in Nakaseke district, Uganda

Rehabilitation of the degraded pasture and rangeland ecosystems. A total of 405 acres of the degraded pasture and rangeland ecosystems were established on 46 private beef farms across the nine districts under the MOBIP-RAWM project. On average, 9 acres of degraded pasture and rangeland ecosystems were restored and propagated with elite Chloris gayana and Centrosema pubescens species. The pasture rehabilitation process involved site selection and delineation of the degraded pasture lands followed by bush clearing to remove the shrubs, thickets and tree stamps. Afterwards, tractors and other farm equipment (e.g. hoes) were deployed to plough the cleared land and level the seedbed ecosystem, respectively. Seeds of Chloris gayana and Centrosema pubescens species were sowed and intercropped with the traditional pasture legumes. The rehabilitated pasture land ecosystem was maintained by re-seeding and seasonal weeding cycles.

Restoration of the degraded pasture land ecosystems. A case in point is the rehabilitation of the heavily degraded pasture land ecosystems in one of the pilot beef farms in Nakaseke district (Figure 4). As such, Figures 4a and b show the field photos before the intervention (rehabilitation process) and after rehabilitation with the improved pasture species under the MOBIP-RAWM project.

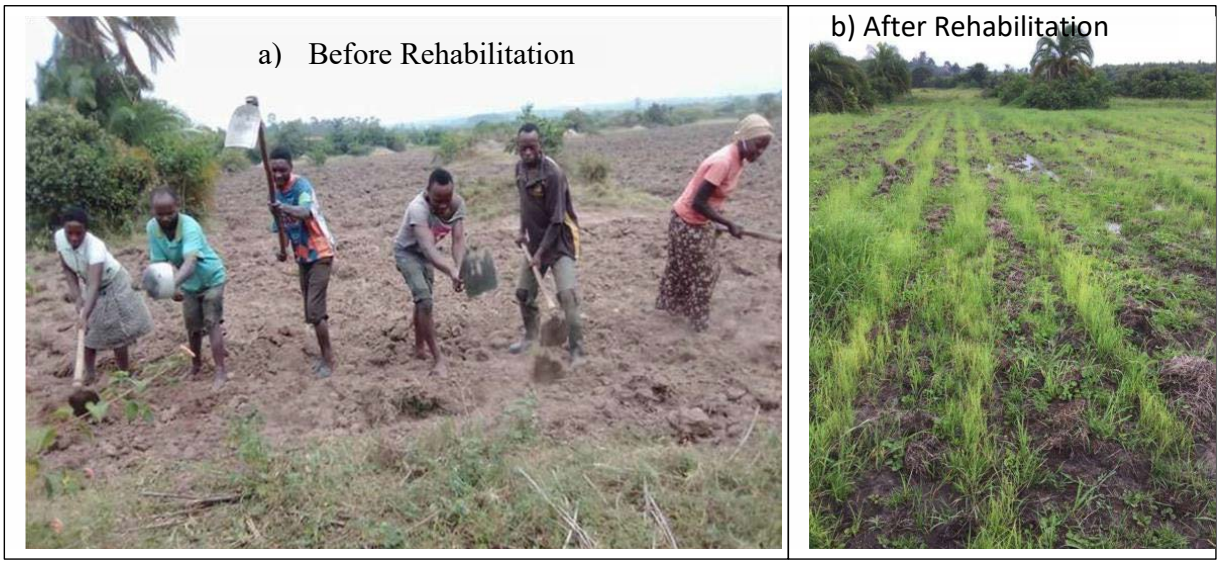

Figure 4. Field photos of the rehabilitated pasture land propagated with the elite *Chloris gayana* and *Centrosema pubescens* at a pilot farm in Nakaseke district, Uganda

Correspondingly, Figure 5 presents the field photos depicting core stages of the rehabilitation process for the heavily degraded pasture land ecosystems. In this regard, Figures 5a, b and b show the field photos of the three major processes (thus, before, during and after restoration) of the severely degraded pasture lands under the MOBIP-RAWM project.

For the pasture ecosystems that suffered severe dry spells, the dry grass was cut and used as mulch during zero or minimum tillage pasture cultivation systems. The dry grass provided biomass which transformed into mulch during the pasture land ecosystem restoration process. Afterwards, the seedbeds were planted or re-seeded with the Chloris gayana and Centrosema pubescens intercrop. Figure 6 presents a case study of zero tillage pasture cultivation systems at a Lubobo pilot farm in Nakasongola district.

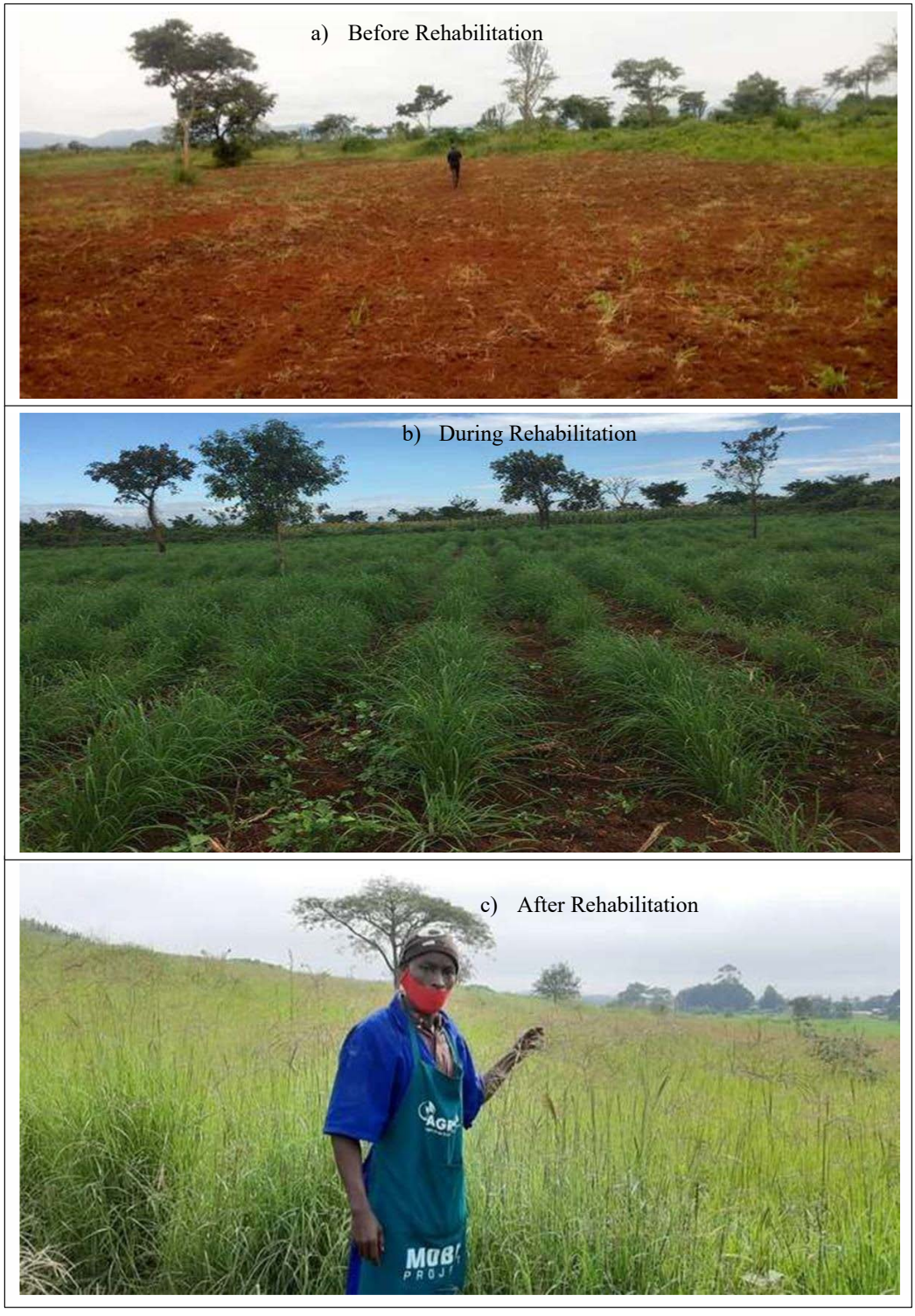

Figure 5. Field photos showing the major rehabilitation processes (before, during and after) for restoration of degraded pasture ecosystems, at a model farm in Masindi district, Uganda

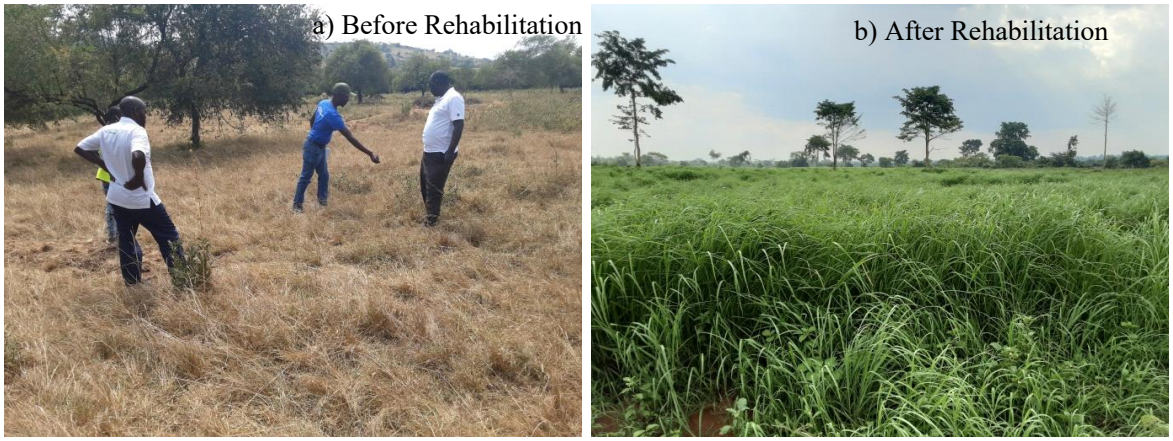

Figure 6. A field rehabilitated with Chloris gayana and Centrosema pubescens on Lubobo's Ranch, one of the MOBIP-RAWM pilot farms in Nakasongola district, Uganda

Restoration of the degraded rangeland ecosystems. Most of the degraded rangeland ecosystems were infested with diverse species of obnoxious weeds, termites and invasive scrubs. As part of the restoration efforts, preliminary activities included bush clearing to remove aggressive invasive shrubs, termite control and weed to spot removal of enormous unpalatable herbaceous weeds in selected rangeland ecosystems. Figure 7 shows photos taken during the restoration of the degraded rangeland ecosystems.

Promoting agroforestry in the degraded rangeland ecosystems. Agroforestry tree seedling production nurseries were established in the nine project districts. The nurseries acted as field sites to showcase sustainable practices during the commercial production of multipurpose tree seedlings. Figure 8 presents field photos for some of the agroforestry tree nurseries established under the MOBIP-RAWM project.

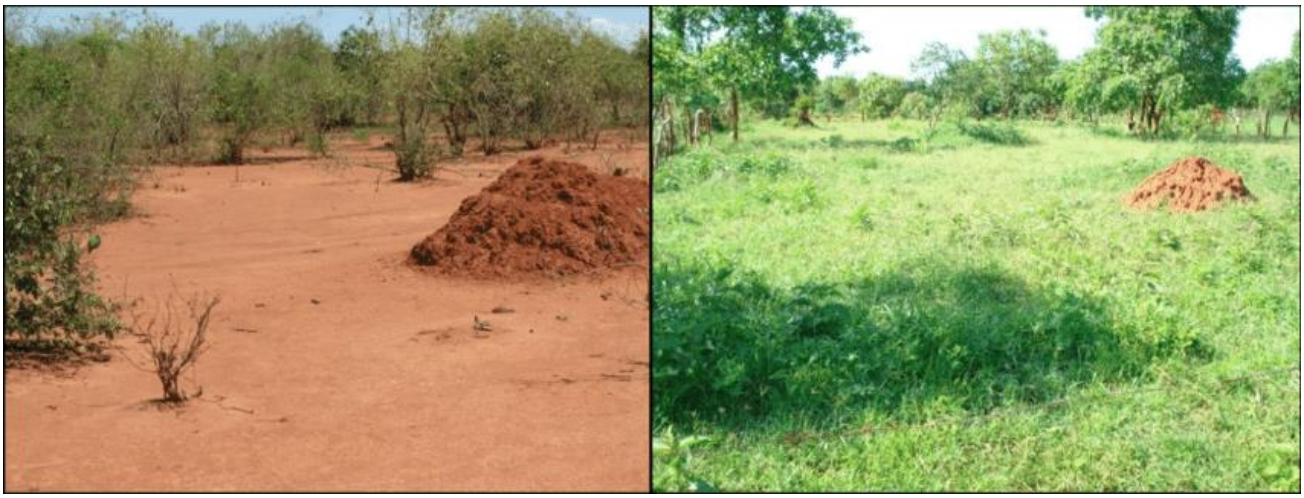

Figure 7. The degraded and rehabilitation rangeland ecosystem, on one of the pilot farms, in Kiboga district, under the AGRENES MOBIP-RAWM project, Uganda

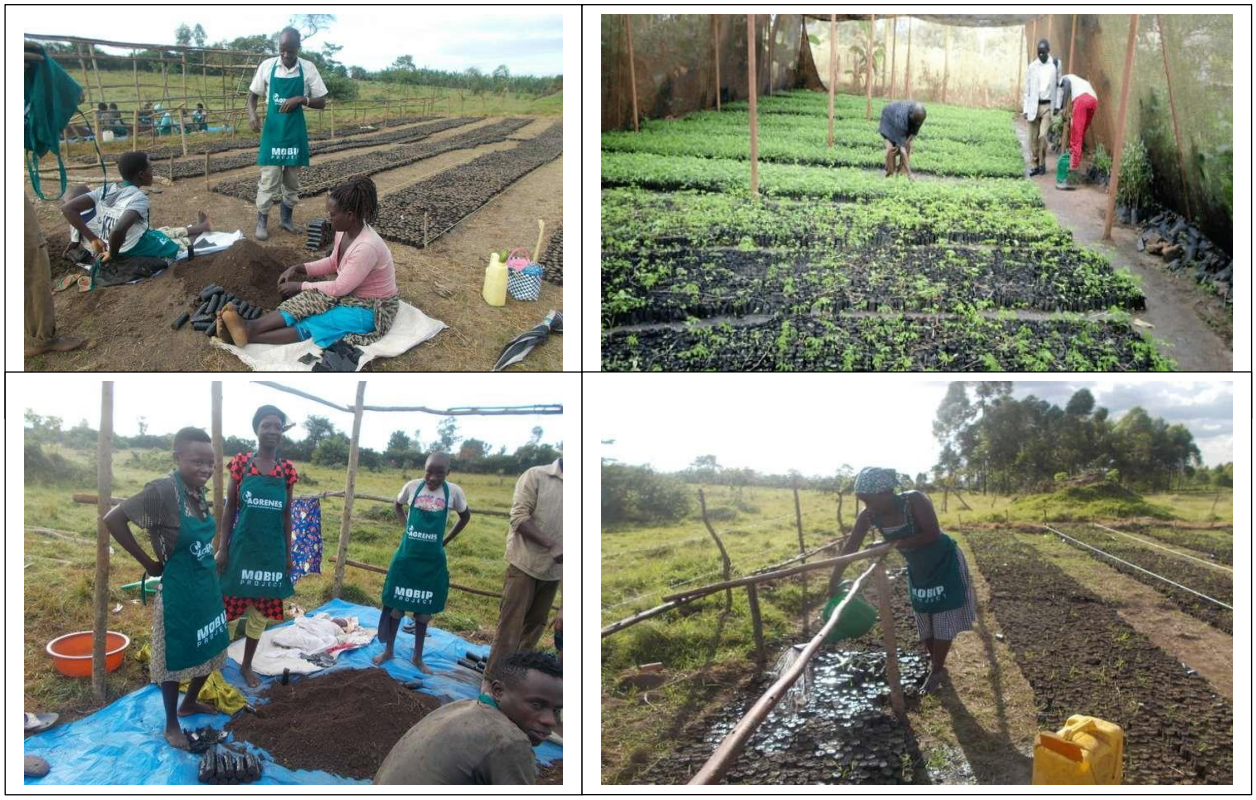

Figure 8. Field photos for establishment processes of the pilot agroforestry tree nurseries at a pilot farm in Wakyato village, Nakaseke district, Uganda

The 325,800 seedlings of six types of improved tree species were produced, namely *Grevillea robusta, Maesopsis eminii, Markhamia lutea, Tamarindus indica, Albizia Chinense* and *Calliandra callothyrus*. The tree seedlings were planted to provide shade, forage, nutrient recycling, live fences for the pasture and rangeland ecosystems, windbreaks, conservation of soil moisture and biodiversity, and ecosystem restoration. Table 4 presents a summary of the most dominant agroforestry tree seedlings produced in the commercial nurseries and established at the MOBIP-RAWM project sites and farms.

Table 4. The most dominant tree species and seedlings produced and propagated

The most dominant tree species established	The spacing used in tree planting (m)	Number of new seedlings got	Area planted/ covered by the trees (Acres)
Grevillea robusta	100	40,000	100
Maesopsis eminii	30	15000	3000
Markhamia lutea	30	8000	1600
Tamarindus indica	10	7000	70
Calliandra callothyrus	2	250,000	250
Albizia Chinense	30	80000	16000
	Total	400,000	21,020

In summary, the seedlings were produced in the nurseries and given to 81 farmers across the nine districts under the MOBIP-RAWM project. On average, each of the beneficiary farmers received nearly 4,000 seedlings for propagation on their farms and in the degraded rangeland ecosystems. Approximately 35% of the agroforestry seedlings were planted as hedgerows, whilst 50 and 5% of the seedlings were planted in silvopasture and forest ecosystems, respectively. The 10% of the seedling produced were used in gap-filling in the hedgerows, silvopasture and forest ecosystems. Figure 9 shows field photos taken during production and propagation of Calliandra trees seedlings as hedgerows at a model Luboboo mixed farm under the MOBIP-RAWM project in Nakasongola district, Uganda.

Figure 9. Field photos for production of the Calliandra seedlings (a-c) and being planted as hedgerow at a Luboboo mixed farm (d), Nakasongola district, Uganda

During the prolonged dry spells between April and May of 2020 that was experienced across the cattle corridor, some of the agroforestry tree seedlings failed to successfully propagate after transplanting. As such, an additional 33,230 tree seedlings were produced and deployed in gap-filling in the agroforestry sites.

Developing capacity of the beef producers and district actors in sustainable and integrated water resources management. Two water facilities were established in each of the nine target districts under the MOBIP-RAWM project to increase availability and last-mile access of quality water resources for beef production. The 18 infrastructures constructed had the storage capacity of 30,000 litres of water, translating into 540,000 cubic litres of water supplied at any time to the beneficiary households for beef production. Out of the 18 households who received the new water facilities, 10 of them were female-headed. Figure 7 shows photos of the water construction process at pilot project sites.

Besides the construction of water facilities, training was conducted to enhance the capacity of the farmers and communities in sustainable and integrated water management schemes. Such training activities included practical modules in the participatory planning and maintenance of existing community water resources, as well as the newly established water infrastructures.

Figure 10. Field photos for constriction of water facilities at Mrs. Tumuhairwe Robinah's farm, a beneficiary beef farmer in Kyankwanzi district, Uganda

Developing capacity of the beef producers and district actors in sustainable and integrated water resources management. Five different types of training materials for agroforestry forage and pasture production were designed and produced. The materials were used in training farmers and also disseminated to different beef farming communities across the nine districts under the MOBIP-RAWM project. Figures 8 presents cover page photos for the new forage guides and pasture albums designed and produced by AGRENES under the MOBIP-RAWM project.

Achievements

Enhanced capacity for forage production and rehabilitation of degraded rangelands. Below is a summary of the MOBIP-RAWM project results and outcomes from the pasture establishment and rehabilitation of degraded rangeland ecosystems on beef production. Over 405 acres of degraded rangeland ecosystems were restored, and 483 acres of new pasture fields were established at the household level. About 70 and 30% of the private farms that received the pasture production packages were owned by men and women, respectively. The pasture production and rangeland rehabilitation interventions increased the production and supply of the quality forage and feed resources in the nine districts under the project.

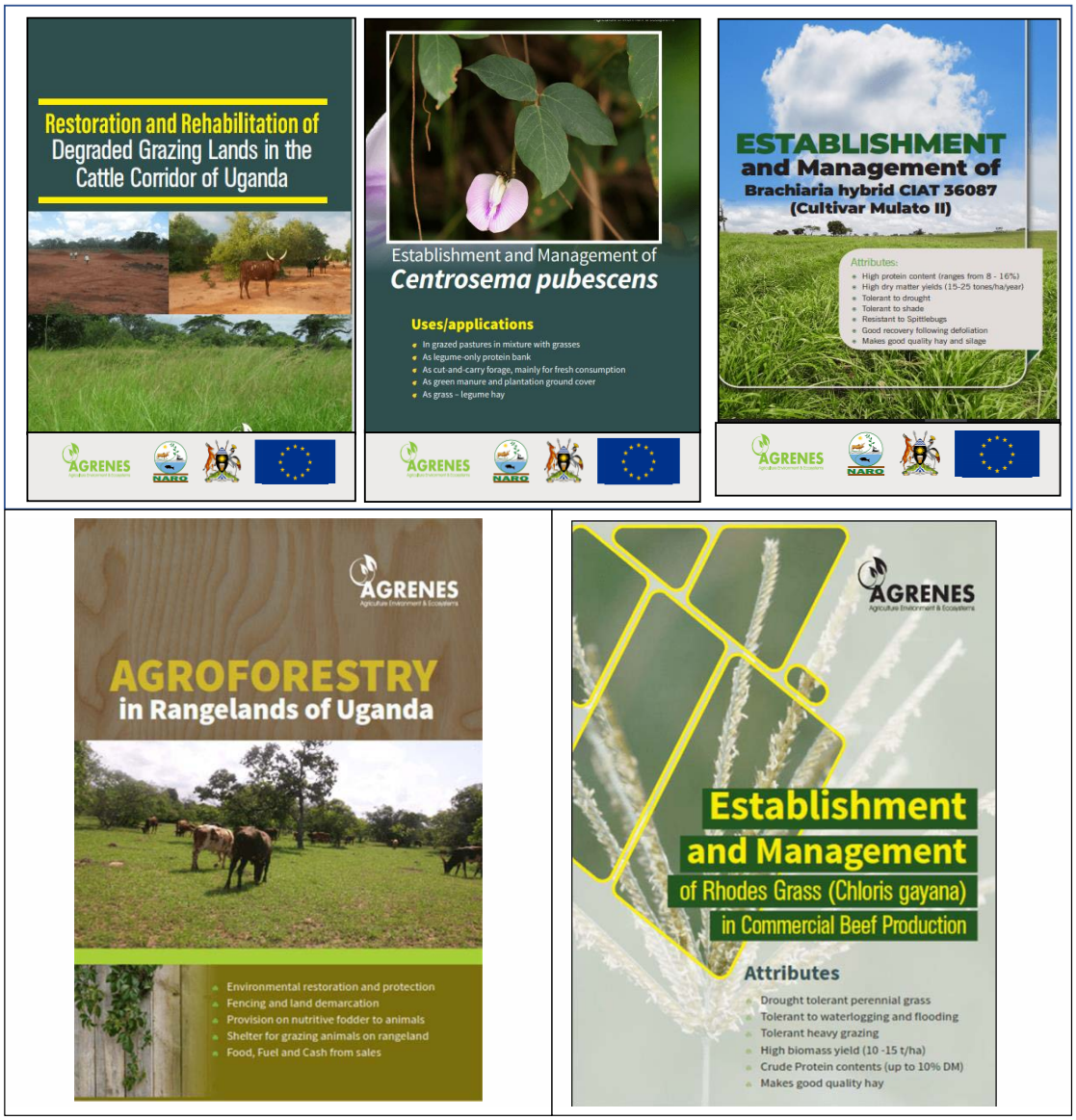

Figure 11. The five forage and pasture training manuals produced by AGRENES under the MOBIP-RAWM project, Uganda

A case in point is the Lubobo ranch, a model farm in Nakasongola district, whose annual pasture dry matter yield of 2 tons/ha and with an animal carrying capacity of 0.6 LU/ha. But after the intervention, dry matter production and carrying capacity of the rehabilitated pasture ecosystems increased three times only during the first six months.

Therefore, rehabilitation of the degraded pasture lands increases pasture yield output, as well as the availability, supply and last-mile access to feed resources by the beef farmers. As such, the number of beef cattle that are supported by improved pastures and rehabilitated rangeland ecosystems increases by at least three folds. The quantity of hay and processed feed resources also increases three times than before the interventions.

Increased productivity of forage seed and feed resources. For the *Chloris gayana*: depending on the soil fertility, environmental conditions and cutting frequency, seed production output ranges between 247-741 kg per acre. Likewise, the highest recorded yield of *Chloris gayana* ranges from 74-100 tons of dry matter (DM) per acre, with an average yield of 40 tons of DM per season (AGRENES 2000a; Ecocrop, 2014; Murphy, 2010). At least 291,460 kg of *Chloris gayana* seeds is produced per season from the project farms, with a mean seed production rate of each farm being 494 kg per acre per season. The average seasonal feed production rate for each farm was 40 tons. Similarly, at least 23,600 tons (or 21,405,200 kg) of DM were produced across the nine districts every season.

For the *Centrosema pubescens*: Nworgu and Ajayi (2005) reported that the biomass and DM yield of C. pubescens is 18.6 and 9.3 tons per acre per year, respectively. A total of 3,534 and 1,767 tons of biomass and DM yield were produced from the established pasture gardens and rehabilitated rangeland ecosystems, respectively. Results for the yield turnover suggest that at least 3,205,992 and 1,602,996 kg of biomass and DM yield were produced annually from the new pasture gardens and rehabilitated rangeland, respectively. Figure 9 shows photos of the harvested hay at Lubobbo farm in Nakasongola district, a beneficiary model farm under the MOBIP-RAWM project. Below are some of the fresh pastures, harvested and processed hay in the beneficiary communities (Figure 9).

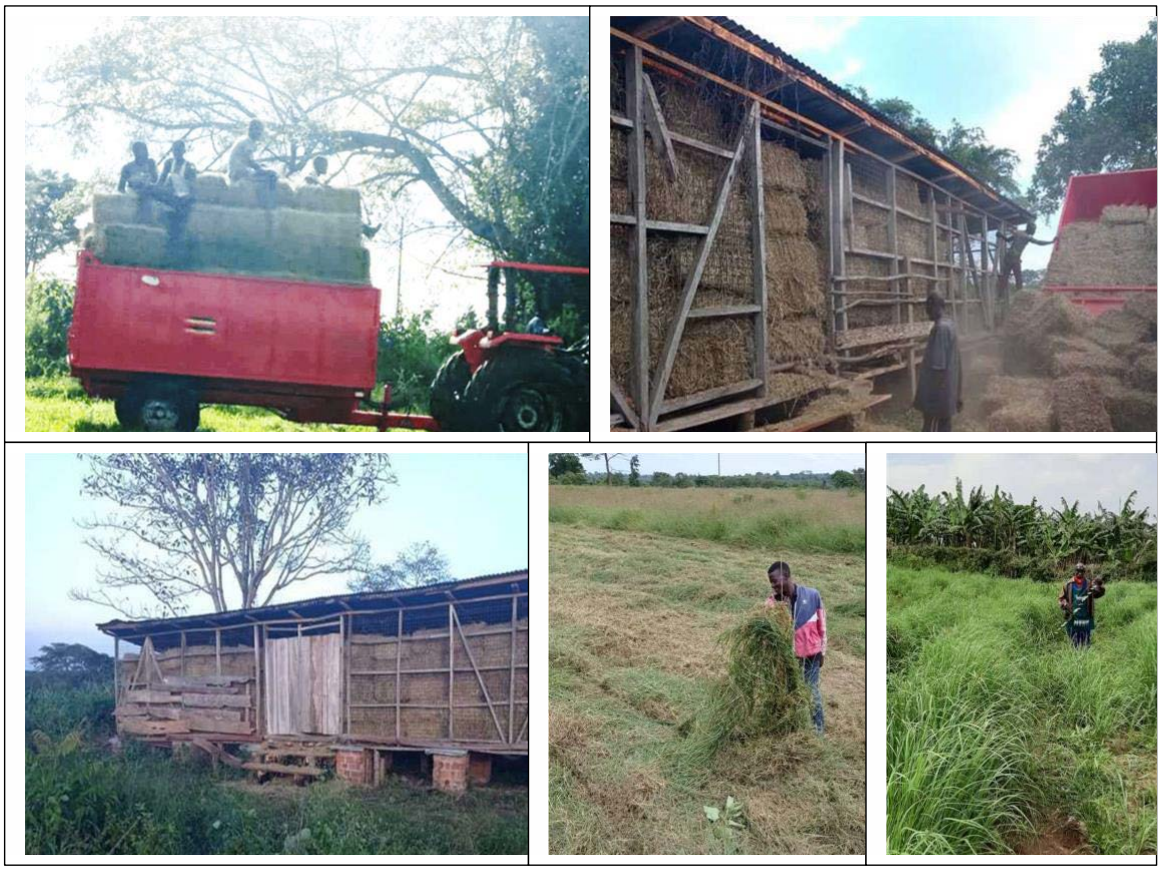

Figure 12. Photos of fresh pasture, harvest and processed hay of the harvested hay at a model Lubobbo farm in Nakasongola district, Uganda

After demonstrating the importance of improving forages mainly in terms of the yield output, the results stimulated the demand for cultivating more acreage of improved pastures. In the end, the farmers co-funded the establishment of extra 125 acreages of improved pasture for their beef cattle. They also rehabilitated 140 acres of degraded rangeland ecosystems through re-seeding and over-sowing practices with the improved pasture seeds. Consequently, these demonstrations have stimulated demand for improved pastures, mainly the *Chloris gayana* and *Centrosema pubece* across the project districts, and definitely have spillover in non-beneficiary farmer communities across Uganda.

Increased incomes from pasture seed, hay and other feed resources. The economic impact of improved pasture was determined using the Returns on Investment (ROI) approach. The ROI model was calculated using the Benefit-Cost Ratios (BCRs) tool, as described by Boardman *et al*. (2017). Henceforth, the cost of pasture establishment and rehabilitation was estimated based on the present market value of the pasture produced. In this context, the data show that the cost of producing *Chloris gayana* is Uganda Shillings (UShs) 25,000 per kg, inclusive of the transportation and marketing costs. The exchange rate between United States Dollars (1 USD) to UShs is 3,520. With the present market value and selling price of *Chloris gayana* being UShs 45,000 per kg, the sales translate into a net revenue of UShs 20,000 per kg. Over 291,460 kg of Chloris gayana seeds are produced each season from the pasture gardens and rangeland ecosystems. As such, farmers earn total net revenue (profits) of UShs 5,829,200,000 per season from the sale of pasture seeds alone. Similarly, the mean market price of hay is UShs 300 per kg, less the cost of hay bailing. Therefore, if all the *Chloris gayana* dry matter (DM) is turned into hay, it gives a total of 21,405,200 kg of DM and revenue of UShs 6,421,560,000 each season. The production costs and market prices suggest that the BCR for the Chloris gayana seeds and hay is 2.11 and 2.12, respectively.

For the *Centrosema pubescens*: the fresh biomass is fed to the beef cattle as forage mainly under the zero-grazing and cut and carry farming systems whilst the DM is used to produce hay. The production cost of hay for the *C. pubescens* is UShs 35,000 per kg, inclusive of the harvesting and processing costs. The current market price for hay is UShs 60,000 per kg, and it translates into a proportionate net income or profit of UShs 25,000 per kg of hay produced. Therefore, the annual yield of 1,602,996 kg of DM from the *C. pubescens*, bringing in total net revenue of UShs 40,074,900,000 annually; to all the project beneficiary beef farmers.

Contribution of agroforestry tree seedlings on forage and beef production. Agroforestry, when integrated with elite forage species, could play a critical role in feeding beef cattle essentially during the prolonged dry spells when the herbaceous forages, hay and other feed resources are scarce. Sèwadé *et al*. (2017) developed a dendrometric measurement model for estimating forage biomass of multipurpose trees using the dendrometric parameters including the girth at breast height (BDH), total height, and stem height and crown diameter.

The model employs a stepwise multiple regression to establish the relationships between the dendrometric morphological traits, aerial fodder biomass and the livestock carrying capacity. According to the model, the average forage biomass from the multipurpose tree species was between 10 and 19 kg of DM per tree species. On average, each agroforestry tree produced 14.5 kg DM, as the mean for 10-19 kg of DM per tree given (Sèwadé *et al*., 2017). The mean annual

carrying capacity was 0.012 - 0.016 TCU per acre (Tropical Livestock Unit per acre). In this context, carrying capacity refers to the number of cattle/ animals expressed as the forage biomass harvested from the tree per unit area (an acre) that can feed sustainably in one year. The TLU was also estimated using animals of 250 kg live weight (Sèwadé *et al*., 2017).

Using the estimates of a dendrometric model (Sèwadé *et al*., 2017), the 400,000 multipurpose agroforestry tree seedlings established produce 5,800,000 kg of DM annually. The carrying capacity for the established agroforestry systems ranges from 252 to 336 beef cattle per year. In other words, the multipurpose tree seedlings increased the availability of quality forage, mainly the leaf biomass to feed the beef cattle.

Contribution of the agroforestry on the environment. Generally, agroforestry provides several environmental benefits, particularly when integrated with different multipurpose tree species. The four foremost benefits of agroforestry systems are; (i) climate change mitigation through carbon sequestration, (ii) biodiversity conservation, (iii) soil health enrichment, and (iv) air and water quality improvement. Ecosystems models are invaluable tools employed to estimate plant and soil C stocks and are hence, often used to estimate the carbon (C) sequestration potential of different agroforestry systems, including agro-silvopastoral and silvopastoral systems. The CO_2FIX model developed by Schelhaas *et al*. (2004) is one of the leading models used to estimate C stocks and flows in ecosystems.

Torress *et al*. (2017) used allometric equations from a CO_2FIX model to estimate greenhouse gas (GHG) flux emissions, tree and grass above-ground biomass and carbon storage in the silvopastoral and agro-silvopastoral systems in Brazil, and the number of trees required to offset the GHG emissions. The quantities of GHG emissions and level of C sequestration in agroforestry systems depend on many factors, including species diversity and populations, agronomic practices, soil tilth and health, as well as the micro-climate and weather conditions (Torress *et al*., 2017). However, in general terms, the mean GHG emission from the agro-silvopastoral agroforestry systems is 3.3 tons of CO_2-equivalent per acre (t CO_2e area 1). The carbon sequestration and storage in above-ground trees and grass biomass is 8.4 and 9.3 tons of C per acre in silvopastoral and agro-silvopastoral systems, respectively. The number of trees required to offset the GHG ranged from 42-108 trees per acre (Torress *et al*., 2017).

Based on the aforementioned estimate of Torress *et al*. (2017), the 21,020 acres of the multipurpose agroforestry tree seedlings planted in the modern silvopastoral systems under the MOBIP-RWAM project sequester carbon from the ecosystem, amounting to a total of 69,366 tons of CO_2-equivalent. The carbon sequestration and storage potential in the above-ground trees and grass biomass in all the established agroforestry systems ranges from 176,568 to 195,486 tons of CO_2-equivalent, which is consistent with the populations of multipurpose tree seedlings of 42 to108 trees per acre (Torress *et al*., 2017). Therefore, the established agroforestry systems also serve to sequester more CO_2 from the atmosphere, thereby offsetting the carbon fluxes and making it a climate change mitigation option.

Contribution of the new water infrastructures on beef production. Overall, 18 new water infrastructures were constructed with facilities creating opportunities for harvesting additional rainwater from rooftops of houses. When operated at full capacity, each water facility provides 30,000 litres of clean water for both the livestock cattle and domestic use. This means that the 18

water facilities constructed provide a total of 540,000 litres of clean water for beef production. Water is a limiting factor to beef production in the nine districts of the cattle corridor under the MOBIP-RAWM project, especially during prolonged droughts and dry spells. The 540,000 litres of quality water resources created is enough to benefit over 98,182 heads of cattle even during critical dry months of the year. The water facilities save the feeding calves, which cannot walk long distances for water wells.

A case in point is that of Mr Rwakanuma Ephraim, a beef farmer in Kiralamba village, Katuugo parish and Katuugo sub-county in Nakasongola district who says 'Before AGRENES came, I was using a bicycle to fetch water from community water well, which is at a distance of 7 km from here (my home) for domestic use and my goats. This was taking me 3-4 hours of my daily routine because my goats need a lot of water. When you (AGRENES and the MOBIP) AGRENES came, they constructed a water tank or facility accommodating up to 30,000 litres of clean water. I use some of the water to feed my 150 goats and ten beef cattle. I also have enough water for my domestic chores'. The situation is no different from other beef farmers who received the water facilities in the nine districts under the MOBIP-RAWM project.

Challenges faced during project implementation

Challenges due to the outbreak of the COVID-19 pandemic. The outbreak and effect of the COVID-19 slowed down the implementation process mainly for the field activities requiring travel and gathering people, including gathering the beneficiary farmers in one location, to receive the capacity building and training packages.

Challenges in pasture establishment and rehabilitation of rangelands. Besides the disruptions due to Coronavirus (COVID-19) pandemic, the following challenges were faced in the field during the establishment of new pasture gardens and rehabilitation of the degraded rangeland ecosystems. The seeds of the improved forage varieties were of high quality. But the seed had poor germination rates during upon propagation in the new pasture gardens and restored rangeland ecosystems. Poor germination performance of the seeds was caused by adverse abiotic and weather conditions such as dry spells, erratic rainfall, flooding and soil erosion in the target districts and ecosystems.

For instance, in the Nakaseke and Nakasongola districts, most of the farms received erratic and torrential rainfalls after sowing pasture seeds which also brought unprecedented massive erosion. Soil erosion coupled with the high soil moisture content and poor quality of the soils significantly reduced the germination percentage of the sowed pasture seeds from 99 to 70% (for the surviving forage or pasture acreage after germination). As a result, we incurred additional costs in the purchase of extra pasture seeds, labour and other re-seeding activities.

Challenges during the establishment of agroforestry. Initially, before COVID-19, farmers were mobilized and trained in commercial agroforestry. But the pandemic had restrictions in travel of project staff but most importantly, a ban on the community gatherings. This means that farmers could not be gathered into community groups for agroforestry training activities. Yet the tree seedlings were growing very fast and could be lost if not transplanted from their nurseries in time. Faced with the challenge of the outgrowing seedlings, the team resorted to training farmers and transplanting the seedlings on individual farms. In the end, AGRENES incurred additional costs, mainly those involving the purchase of nursery tree shade nets, transportation and facilitation

of the team to plant the multipurpose agroforestry tree seedlings on individual farms for the beneficiaries rather than group training.

Lessons learnt and emerging opportunities

Improved pastures and rangeland rehabilitation. A well-established Rhodes grass garden produces about 500 - 600 kg of dry matter per acre, which is enough for eight beef cattle. The observation is consistent with the standard carrying capacity of 5-10 cattle per acre of Rhodes grass pastures when harvested and converted into hay to dry season feed and animal feeding management (AGRENES 2000a; Murphy, 2010; Ecocrop, 2014). These production statistics suggest that a net total of 590 acres of the Chloris gayana was produced by the end of the project. The data suggest that the new pasture gardens have a carrying capacity of between 2,950 and 5,900 beef cattle per season. Likewise, the additional fresh biomass from the Centrosema pubecen pastures provides the extra carrying capacity of 4,500 beef cattle per season.

The payback periods for the investments made in the production of improved pastures (thus, *Chloris gayana* and *Centrosema pubecen*) was only one season. In both cases, the returns on investment more than double the cost of the investment and multiplier effects by stabilizing feed availability, especially during dry seasons, will be realized in at least a 40% increase in milk yields and animal growth rates.

Although both forages are drought-tolerant, *Chloris gayana* is more productive and is the most preferred forage species by most beef farmers. Unlike other traditional forage species, farmers are able to harvest seeds and dry matter every season for selling and feed production, respectively. Besides selling, harvested seeds are consumed and can also be used to establish or expand to new pasture gardens. Henceforth, farmers with the established *Chloris gayana* gardens have substantial production of hay and feed. Chloris is already boosting household incomes and food security for the beneficiary farmers.

Given the context of existing gender disparities in the beef sub-sector where women hardly have any access to productive assets and opportunities, including the pasture gardens and rangelands, especially in the target districts, efforts have been made to benefit more women, beef farmers. At least 30% of the improved pasture gardens are established on the farms owned by women. About 28% of the rehabilitated pastures and rangeland ecosystems are owned by women. Although men are still dominant in the beef sub-sector, the supported women-led farms are expected to contribute to beef production with spillover to other economic local enterprises such as agro-input dealerships and local seed businesses

Emerging opportunities from the project interventions. The auxiliary opportunities are emerging as a result of implementing the AGRENES MOBIP-RAWM project in the key intervention areas: pasture establishment and rehabilitation in the degraded ecosystems, sustainable agroforestry and integrated water management systems.

Opportunities from the improved pasture gardens. The project has stimulated demand for and also increased the supply of the improved forage species, mainly *Chloris gayana* and *Centrosema pubescens*. The supplementary advantages of *Chloris gayana* are: i) it's a drought-tolerant perennial grass; ii) tolerant to abiotic stress like the waterlogging and flooding; iii) tolerant heavy

grazing; iv) has a high biomass yield (10-15 t/ha); v) high crude protein contents (up to 10% DM), and vi) makes good quality hay.

The supplementary advantages of Centrosema pubescens include, among others, that can be mixed in grazed pastures with grasses: i) as legume-only protein bank; ii) as cut-and-carry forage, mainly for fresh consumption; iii) as green manure and plantation ground cover, and iii) as grass-legume hay.

Opportunities from the agroforestry tree seedlings. The agroforestry tree seedlings produced in the nurseries will be useful for:
a) planting in degraded catchments/watersheds for land restoration
b) protection against erosion while providing other services such as
c) nitrogen fixation and provision of
d) increase fodder for cattle and other animals

Opportunities from the new water facilities established. The new water facilities constructed will increase the availability and distribution of water for animals. The provision of quality water facilities and resources at the household level limits the congregation of animals in specific points at communal water facilities, which often leads to trampling and degradation of the water for production.

In addition to supporting beef production, the project water facilities will be used for: i) irrigation of agroforestry tree nurseries, ii) provision of water for calves which graze close to homesteads; and iii) domestic use - frees labour which would be invested in fetching water over long distances to rangeland management activities.

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