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Mountains ADAPT

Solutions from East Africa

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ADAPTATION AT ALTITUDE
Taking Action in the Mountains

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Authors

United Nations Environment Programme: Sabine McCallum, Ansgar Fellendorf
GRID-Arendal: Torjus Solheim Eckhoff, Laurent Fouinat
Albertine Rift Conservation Society: Godfrey Mwesigye, Sam Kanyamibwa

Contributors

In-depth information about mountain adaptation solutions has been provided through highly valued contributions from (listed after numbering of solutions in this booklet):
Ladislaus K. Leonidas (EAC Secretariat, Tanzania)
(1) Kasereka J. Muranga (REMODA, Uganda)
(2) Doris Mutta (African Forest Forum, Kenya)
(3) Anna E. Lawuo (Ministry of Tourism and Natural Resources, Tanzania)
(4) Chris Magero (IUCN, Kenya)
(5) William S. Mwakilema (Tanzania National Parks, Tanzania)
(6) Sixbert Mwanga (Climate Action Network Tanzania, Tanzania)
(7) Sarah Kigongo (IGCP, Uganda)
(8) Maureen Anino (Ministry of Environment, Uganda)
(9) Pantaleo Munishi (Sokoine University of Agriculture, Tanzania)
(10) Alain Ndoli (IUCN, Rwanda)
(11) Paul Demetry (Ministry of Environment, South Sudan)
(12) George Mwaniki (National Environment Trust Fund, Kenya)
(13) John Berchmas Habumugisha (Muhisimbi Voice of Youth in Conservation, Rwanda)
(14) Nzigiyimpa Leonidas (APMB, Burundi)
(15) Marshall Banamwana (Ministry of Environment, Rwanda)
(16) Alphonse Polisi (ABN, Burundi)
(17) Paul Gacheru (Nature Kenya, Kenya)
(18) Bernadette Habonimana (Université du Burundi, Burundi)

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Illustrations: Elise Gunstvedt and Hasan Abbas, GRID-Arendal

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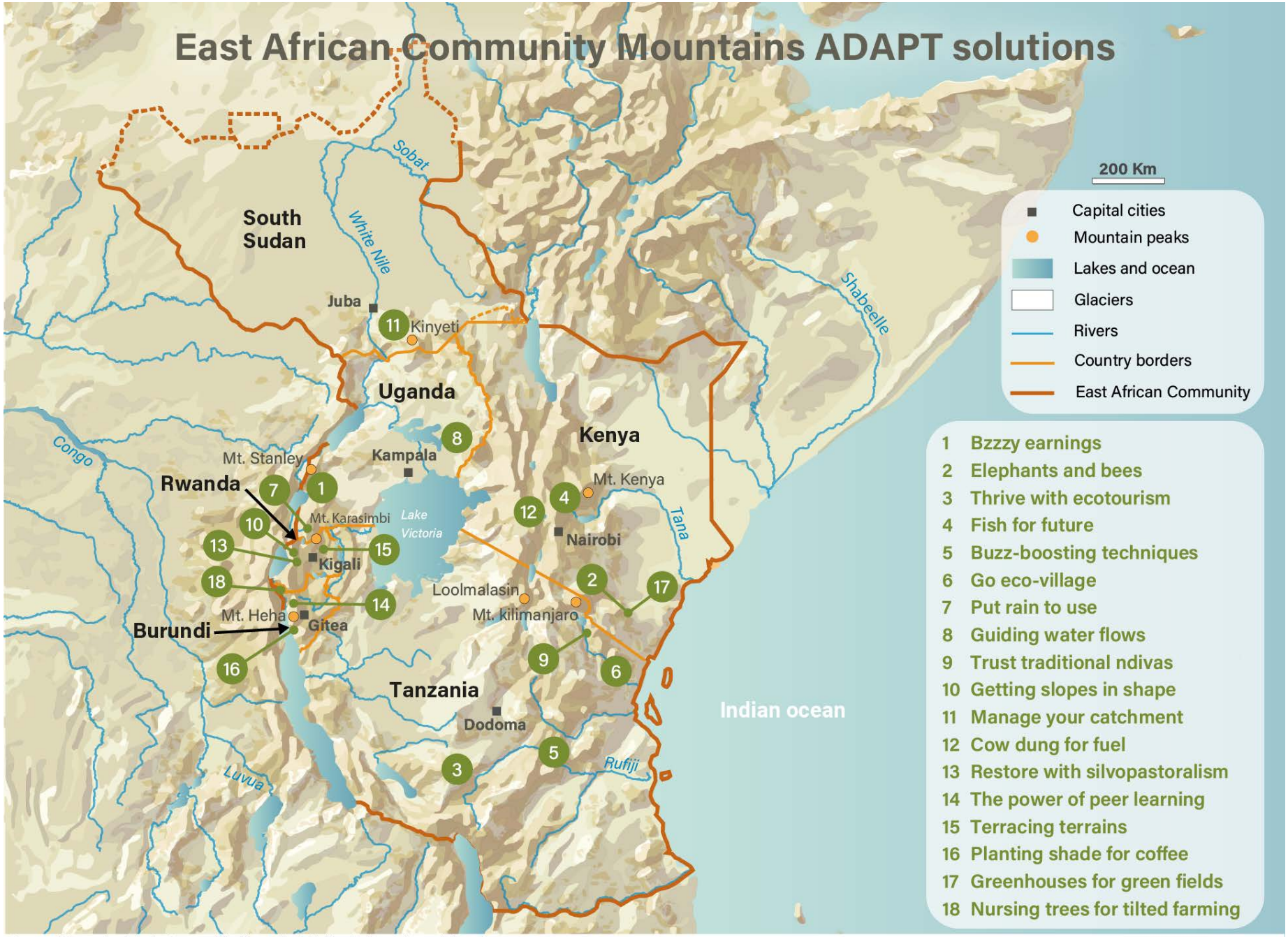
Mountains ADAPT

Solutions from East Africa



Source: Mountain delimitation modified from K3 definition in Kargulle et al. (2017).
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GRID-Arendal (2022)

Mountains ADAPT

Solutions from East Africa

Contents

Acronyms

ABN	Association Burundaise pour la protection de la Nature
AFR100	African Forest Landscape Restoration Initiative
APMB	Association pour la protection des montagnes du Burundi
ARCOS	Albertine Rift Conservation Society
CRAG	Climate Resilient Altitudinal Gradients
CSA	Climate smart agriculture
EAC	East African Community
EAMCEF	The Eastern Arc Mountains Conservation Endowment Fund
EbA	Ecosystem-based Adaptation
EWMR	Embedding Integrated Water Resource Management
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field Schools
FONERWA	National Fund for Environment
GEF	Global Environment Facility
GIS	Geographic information system
IGCP	International Gorilla Conservation Programme
INRM	Integrated natural resource management
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
IUCN	International Union for Conservation of Nature
JEG	Jitunze Environmental Group
JICA	Japan International Cooperation Agency
LAFREC	Landscape Approach to Forest Restoration and Conservation
masl	meters above sea level
NbS	Nature-based Solution
NGO	Non-Governmental Organisation
PADZOC	Sustainable Coffee Landscape Project
REGROW	Resilient Natural Resource Management for Tourism and Growth
REMA	Rwanda Environment Management Authority
REMODA	Rwenzori Mountain Development Association
RFS	Resilient food systems
RWHT	Rainwater harvesting tanks
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable Development Goals
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USD	United States Dollars (currency)
VSLA	Village Savings and Loan Association
W4EE	Water for Eastern Equatoria
W4V	Water for Virungas
WUA	Water user associations

Intro

A few words about ...

...the context

Climate change is disproportionately affecting mountain regions and their communities across the world with an amplified rate of warming compared to lower elevations and leading to rapidly changing conditions. Mountains provide a range of ecosystem services and goods that are an important source of future agrobiodiversity, water supply, and associated poverty alleviation and sustainable development at local, regional, and international levels. This decline has altered the frequency, magnitude, and location of most related natural hazards that expose mountain communities to higher risks (Hock et al. 2019). These trends are expected to continue and their impacts to intensify, posing increasing challenges for water supply, agriculture, biodiversity, disaster preparedness and tourism (Intergovernmental Panel on Climate Change [IPCC] 2021). It is therefore crucial to identify, develop, transfer, and implement practical mountain adaptation solutions.

In this context, the global programme Adaptation at Altitude: Taking Action in the Mountains,[1] funded by the Swiss Agency for Development and Cooperation (SDC), aims to increase and share knowledge of appropriate climate change adaptation solutions in mountains, and feed it into science-policy platforms for better informed decision-making. The Adaptation at Altitude programme improves the availability and use of mountain observation data and information, strengthens regional science-policy dialogue platforms, increases knowledge on mountain adaptation solutions and influences global policy processes to mainstream climate change adaptation in mountainous regions. The target mountain ranges are found on four different continents, stretching from the Andes, over the East African mountains, the South Caucasus to the Hindu Kush Himalaya. The solutions showcased in this booklet form part of a wider collection of adaptation solutions from across the mountain world, which are presented in an online solutions portal on the programme website.

[1] www.adaptationataltitude.org

...the East African region

This booklet zooms in on concrete adaptation solutions in the mountains of the East African Rift, where tectonic activity of the continental shelves has molded impressive peaks and elevated plateaus. The publication covers the partner states of the East African Community (EAC) Burundi, Kenya, Rwanda, South Sudan, the United Republic of Tanzania and Uganda. The region hosts the continent's highest and only glaciated peaks, namely Mount Kilimanjaro, Mount Kenya, and the Rwenzori Range. It is also home to some of the world's richest mountain biodiversity and iconic animals, such as the endangered mountain gorilla found in the Virunga Mountains.

Reasons for biodiversity and resource degradation are often well known and are strongly interlinked with human activities that could be altered to relieve pressure on the ecosystems. Agriculture is the main source of livelihoods, and as the rapidly growing population attempts to increase food production, fields tend to encroach on the natural and forested landscapes. Land degradation and deforestation have been pressing concerns. A combination of poor management, unsustainable practices and climate change has led to issues such as increased erosion, human-wildlife conflict, biodiversity loss or lower yield production and water scarcity.

The mountain communities are relatively poor, have less access to education and healthcare than in the cities, and are closely interlinked with and depend on their surrounding natural environment. As many as 80 per cent of rural inhabitants are farmers (East African Community [EAC] 2020). This makes the mountain inhabitants of the EAC region particularly vulnerable to the effects of climate change, which is already altering the fundaments of their livelihoods.

...climate change and socioeconomic challenges

East Africa`s mountains have already witnessed warming temperatures, increased risk of more severe extreme events with extended drought periods in some months, as well as heavy rain events that are predicted to further increase in frequency and intensity (Ongoma, Chen and Gao 2018; Ngoma et al. 2021). The World Meteorological Organization (2021) estimates that all remaining African glaciers in Kenya, Tanzania and Uganda are expected to disappear by the middle of this century. Climate change is an additional burden to other challenges in the region, such as economic constraints, poor infrastructure access, and low electrification rates, which reduce rural communities' resilience towards climate change. Firewood and charcoal remain important fuels to cover basic energy needs (EAC, UNEP and GRID-Arendal 2016; Falchetta, Hafner and Tagliapietra 2020). In addition, increasing population density and unsustainable farming practices are putting local environments under heavy pressure. Climate change and its effects are often an additional trigger exacerbating already existing challenges.

Structural and governmental constraints are limiting efforts to adapt to these challenges, including a lack of climate change considerations in local development

"The mountains of East Africa are special places on Earth. They provide a home to millions of people, host stunning unique wildlife, and are a magnet for visitors from around the world. However, climate change is already drastically affecting our mountains with the last glaciers in Africa disappearing, pressure on land increasing and erratic rainfall patterns leading to floods and droughts in the region.

In this booklet we share some practical solutions from the region that we can apply to adapt. The best solutions work with nature as an ally, use traditional knowledge as well as innovative approaches and promote diversification. Studies have shown that transboundary climate risks and challenges are best addressed through cross-border collaborative approaches where actors engage with one another to identify shared risks and potential solutions. Together with partners such as the East African Community we aim to share and transfer mountain solutions across the region and beyond, leading to enhanced action and resilience for mountain ecosystems, and in turn contributing to sustainable development of the communities that rely on them."

– **Frank Turyatunga**, Acting Regional Director for Africa, United Nations Environment Programme

strategies, indifference towards inclusion of mountain areas in national development and climate change plans, and under-resourced government agencies with limited capacity for adaptation action. At a community level, broadening the understanding of how livelihoods of local mountain communities are conducted and sustained under emerging climatic threats should be the foundation for any successful integration of climate change action into local development (EAC, UNEP and GRID-Arendal 2016; Gaworek-Michalczenia, Sallu and Di Gregorio 2019). Moreover, addressing gender aspects in community-based adaptation is crucial as East African rural women continue to have less access to resources and struggle to participate equally in decision-making processes. As a result, women and girls have a weaker adaptive capacity, leading to larger dependencies and traditional roles at home that are often unpaid and more vulnerable to climatic and environmental changes (Abebe 2014).

What to expect...

...in this booklet

This booklet showcases adaptation solutions proven to be successful in response to specific issues caused or accelerated by climate change that negatively affect mountain communities' livelihoods and ecosystems. These solutions were selected for their inclusive approaches, their potential to be transferred and upscaled, as well as their extended benefits for downstream communities across the region.

The booklet aims to highlight a variety of possible approaches in addressing climate change related vulnerabilities. It focuses on actions and measures that already have been or are being implemented to allow for evaluation of their impacts. Enabling factors are also assessed to show the potential for replication in different sociocultural, ecological, political, or economic contexts, sectors, and geographies.

The objective of the publication is to share knowledge with local, regional, and national policymakers, practitioners, potential donors as well as local communities and the interested public about mountain adaptation solutions. The collection aims to inspire, facilitate, and promote the uptake, transferal, and upscaling of adaptation action in the mountains of East Africa.

...from mountain adaptation solutions

We define adaptation solutions as planned or autonomous responses that address one or several mountain-specific challenge(s) and exploit opportunities to adapt to changing future environments. Thus, they represent mountain-specific interventions that build socioecological resilience, strengthen adaptive capacity, and contribute to climate-resilient development pathways. As such, the solutions benefit people's livelihoods and income opportunities, and further support healthy mountain ecosystems.

How we gathered solutions...

...along six key dimensions

Adaptation solutions were gathered and selected following a step-by-step process along six key dimensions to qualify for a mountain adaptation solution:

- relevance in addressing at least one mountain-specific climate change risk.
- practicality and feasibility of implementation in terms of human and financial resources available.
- direct benefits and co-benefits to the environment, the economy, and society, especially with regards to gender equality and empowering women and girls.
- flexibility and robustness in terms of effectiveness under a range of different climatic and socioeconomic development scenarios.
- potential for adjustment, replication, or upscaling in other geographic, social, or sectoral contexts.
- political, cultural, and social acceptability and coherence with existing or planned policies at the local, regional, and national level.

...with our step-by-step approach

In a first step, an initial broad scoping on ongoing and recently finalized adaptation activities was completed through a questionnaire and follow-up interviews with experts from academia, international organisations, local associations, and non-governmental organisations (NGOs) across the six EAC Partner States. A total of 52 solutions could be identified from various sectors, differing levels of implementation, and a range of executing entities and donors. Taking into consideration, among other aspects, the thematic balance, country coverage, inclusive approaches such as Ecosystem-based Adaptation (EbA[2]), types of solution-providers, and information available, 18 solutions were selected to be further investigated for the purpose of being featured in this booklet.

What we learned ...

Although all solutions are context and site specific,

- they share certain enabling factors for successful implementation, i.e., local community support, economic and other co-benefits, as well as incorporating traditional knowledge and socio-economic practices.
- climate change is most often "only" an additional trigger for adaptation action.
- size and coverage of solutions implemented largely depend on availability of and access to financing mechanisms (with international donors providing the largest contributions).
- types of solutions not only refer to specific climate risks, but rather to the broader context (e.g., geopolitical, socio-economic) in which they are embedded.
- only a few solutions are linked to the direct implementation of national adaptation plans and strategies.

Whom to thank for ...

Most of the solutions showcased are associated with development projects, with a variety of solution providers highlighted. Some can be considered bottom-up, whereby local actors initiated action, while others stem from donor-driven projects initiated by national, regional, or international actors. Bottom-up solutions include business ventures taking advantage of local niches, or the revitalization of traditional knowledge that has been in the community for generations. Donor-driven projects are often bigger in scope and span, from projects implemented in a single community to large-scale projects covering several regions in multiple countries.

Some background on...

...how the solutions are described

The solutions featured in this booklet are structured along five overarching themes that outline the broader context:

- Diversified livelihoods with climate and biodiversity benefits
- Water harvesting and retention
- Renewable energy
- Ecosystem restoration
- Climate-smart agriculture and agroforestry

The 18 solutions presented in this booklet under these themes have been implemented or are being implemented at the time of writing in six countries of the EAC. These solutions are designed to bring multiple benefits, such as improved local resilience and biodiversity, and a better life with diversified income opportunities for the people in the communities in which they are implemented.

...which issues are addressed

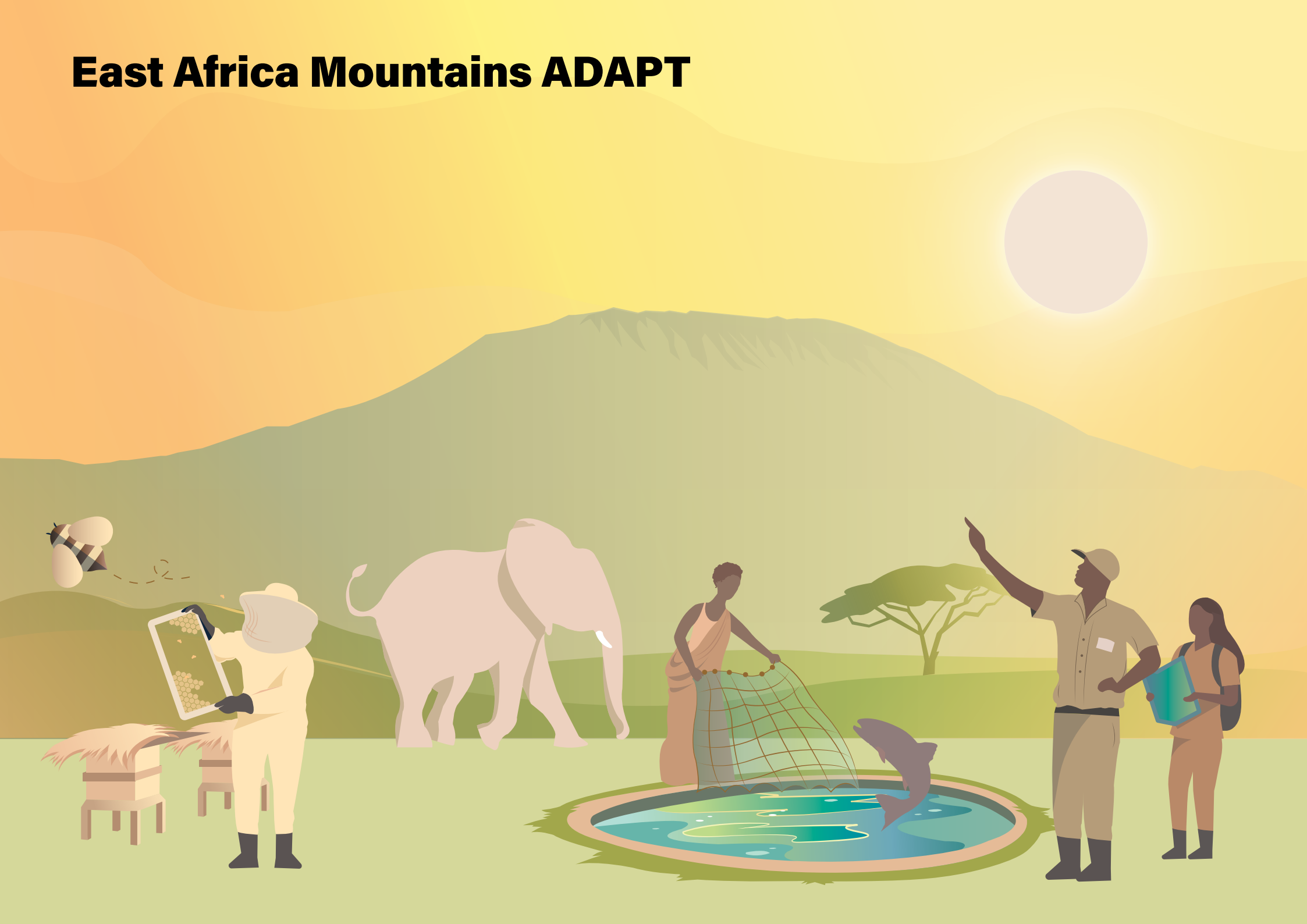
The solutions focus on essential aspects of adaptation in mountain areas, and attention is paid to implementation strategies, financial schemes, local voices, gender equality and success factors such as ownership and co-creation of the local communities. Some of the solutions are Nature-based Solutions (NbS[3]) and Ecosystem-based Adaptation (EbA), using both traditional and new technologies. An important aspect is the restoration of mountain ecosystems as land degradation is an increasing issue that directly affects communities in the EAC mountains, where agriculture is the main source of income for households. Several solutions include mountain restoration activities, relating well to the 2021-2030 United Nations Decade of Ecosystem Restoration[4] which aims to prevent, halt and reverse the degradation of ecosystems on every continent and in every ocean.

[2] Ecosystem-based adaptation (EbA) is "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. It aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change" (Convention on Biological Diversity [CBD] 2009)

[3] Nature-based Solutions are actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits (United Nations Environment Assembly 2022)

[4] https://www.decadeonrestoration.org/

East Africa Mountains ADAPT



SOLUTIONS

Diversified livelihoods with climate and biodiversity benefits

Diversifying the activities supporting every-day life through creating new income opportunities is not only improving the economic situation of local communities but also reducing risks associated with overdependence on natural resources. Often, this has several co-benefits such as reducing the pressure on the environment, mitigating the risk of natural disasters, and improving gender equality.

Communities in the mountains of East Africa mostly rely on agriculture for their livelihoods, providing food and income to the growing population. Agriculture is one of the sectors significantly affected by climate change. Seasonal variability with more frequent droughts and heavy rainfall events destroys harvests thus reducing agricultural output and increases pressures on arable land. Often, farming areas encroach on biodiverse forested areas, causing further environmental degradation and increased rates of soil loss through erosion. Diversification of livelihoods helps mountain communities to better adapt to future changes and become more resilient against climate shocks (Food and Agriculture Organisation [FAO] 2015).

A good understanding of the socioecological context is essential, when developing an adaptation solution that involves livelihood diversification (Wright et al. 2016). Mountain communities in East Africa are unique in terms of the climatic, environmental, social and economic context. This means, that upscaling and transferal of adaptation solutions require approaches tailored to the specific environment and community. Women continue to carry a large burden of the work in food production and the household, making them less responsive to diversification efforts. Hence, it is important to especially empower women and girls in diversifying income opportunities (FAO 2015).

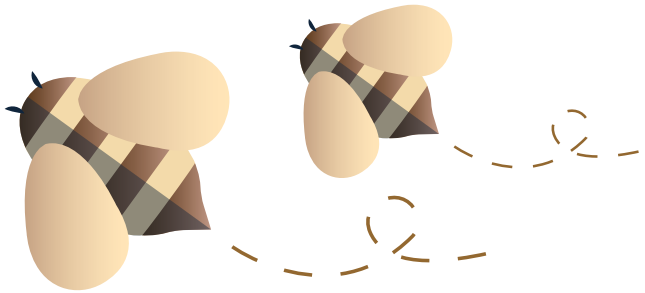
A common theme of the solutions presented subsequently is that they follow an integrated approach in helping mountain communities adapt to climate change while simultaneously providing benefits for their natural environment. Sustainable beekeeping is one such example of a Nature-based Solution (NbS). It supports pollination of natural vegetation and agricultural crops, reduces human-wildlife conflict and produces honey that can be sold in local markets. Creating nature-based activities such as sustainable fish farming in the mountains and a new regional tourism circuit require training and economic investment. Such activities result in job creation, increased awareness for the natural environment´s values and contribute to a sustainable and climate-conscious development of rural mountain areas in the EAC.

Bzzzy earnings

What is the issue ...

The south-west of Uganda features one of the highest mountain ranges on the continent, with the tallest summit Mount Stanley towering at an elevation of 5,109 masl. The Rwenzori mountains are capped by a permanent snow cover and small glaciers, but due to climate change those are likely to disappear entirely in the coming decades (World Meteorological Organization 2021). Most of the mountain range is within the Rwenzori Mountains National Park, and the foothills host many villages and communities, including those in the Kasese district. Most of the mountain population relies on agriculture for their livelihoods, however, the area is prone to frequent flooding that destroys crops and homesteads. For instance, in May and July 2021, two consecutive floods hit communities in Kasese, displacing at least 1,000 people (Davies 2021). Warmer temperatures, prolonged drought and inconsistent rainfall pose challenges for households that are solely reliant on farming.

People living on the mountain slopes often resort to other activities to supplement their livelihoods, such as cutting down trees to collect firewood and selling charcoal. However, as trees have developed root systems that maintain the soil on steep mountainous slopes, deforestation increases the risk of slope instability and erosion, which in turn reduces biodiversity and agricultural output. As climate risks, such as intense rainfall, are expected to intensify, it is important to keep mountain forest cover to combat erosion and reduce the risk of flash floods.



How can it be solved ...

To reduce unsustainable practices such as cutting trees and exploiting other natural resources, diversification of household revenue is necessary for the communities in and around Kasese.

Women in particular carry the main burden of agricultural practices and cooking, which is mostly done with firewood. Therefore, women and girls play a key role in promoting sustainable practices and need to be supported with income opportunities. In 2010, the Rwenzori Mountain Development Association (REMODA) targeted communities in Kasese, specifically women, to offer training for sustainable beekeeping as an alternative source of income. This has been coupled with raising awareness for protecting the local natural environment and ecosystem services.

REMODA`s activities introduced simple ways to build modern beehives and harvest honey without harming the bee colonies. Training was also delivered on where to successfully place new hives, which depends on the accessibility of the terrain and the forage nearby to attract wild bees. Hives can be located on both fertile and non-fertile lands.

The beehives and the colonies are managed by a collective of women. Usually, groups of 8 to 10 women sell their honey and share the revenue earned. Tourism activities in the area support the hosting of a local market in the town of Kasese, ensuring an additional source of income. REMODA monitors and evaluates the work of new beekeepers on a quarterly basis so as to make necessary adjustments to the training programme.

Who is benefitting ...

The beekeeping initiatives have targeted the eastern part of the Rwenzori Mountains, in particular communities around the Buhuhira and Bwesumbo areas in the Kasese district. REMODA has supported over 20 consistent women's groups, with almost 200 women who keep bees as a source of livelihood. This helps sustain their households, generates monthly savings and contributes to substituting unsustainable agricultural practices and deforestation. Many women are interested in beekeeping because it can be easily combined with other tasks at home and in the yard. Even without owning land, beekeepers can install hives and thereby harvest honey, wax and other bee products. This inclusive approach offers not only harvesting of pure bee products but also increases the yield of fruit and vegetables. Pollination leads to fertilization and allows more fruits to grow and increases quality and number of seeds for subsequent years. In addition, beekeeping often involves planting more fruit bushes and trees to supply sufficient food for the bees. This in turn simultaneously increases food production for the local communities.

Members of the groups have encouraged women in other communities to get involved, thereby increasing the interest in beekeeping and environmental protection.

… and how could it work elsewhere?

Beekeeping is an accessible small-scale adaptation solution for many communities and has inspired people in the neighbouring communities outside of Buhuhira and Bwesumbo. The beekeeping project in the Rwenzori Mountains has thrived because it was perceived as a lucrative alternative for income generation. Being "locally-owned" and easy to introduce, it has been empowering the whole community. Women coming together in groups promotes social cohesion, and collective learning helps members to invest into beehives.

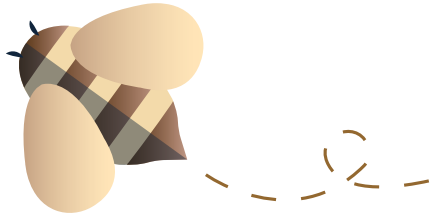
The solution reduces vulnerabilities associated with climate change by fostering awareness for a variety of ecosystem services. Bee pollination increases fertilization of different crops, including locally grown fruit and vegetables, allowing communities to harvest varied and healthy food. Maintaining a natural environment is essential for beekeeping and includes planting trees and other crops, thus keeping vegetation cover on mountain slopes for erosion control. An important enabling factor has been the access to a market. This makes it easier for the beekeepers to sell their products with minimal transport costs. A challenge faced initially was a lack of equipment for honey processing and packaging, however, this can be locally manufactured at little cost.

> *"Beekeeping and honey production on the slopes of Rwenzori has improved the community's livelihoods by reducing poverty among our communities, especially for women who are producing honey for home consumption while the surplus is sold for income generation.*
>
> – Kasereka J. Muranga, Director REMODA

Support can be received from the BeeSupport foundation, which advises local communities on professional training and helps with investments, including for purchasing beekeeper clothing, smokers and other beekeeping equipment.

Community training for women on beekeeping in Kasese district, Uganda ©REMODA

Members of a Kasese community group during a meeting ©REMODA



Elephants and Bees

What is the issue ...

The Taita Hills Wildlife Sanctuary is located in southern Kenya near the Tsavo West National Park, which is designated as a biodiversity hotspot by the United Nations Educational, Scientific and Cultural Organization (UNESCO). The sanctuary is home to numerous plants and mammals, including elephants, roaming freely across the landscape. The area has been affected by changing rainfall patterns and severe droughts due to climate change, which has driven agricultural expansion into protected areas, degrading indigenous forests and encroaching on wildlife habitats (Pellikka et al. 2013). This has worsened conflicts especially between elephants and people. Elephants are herbivores and as they migrate through the landscape looking for food and water, they often take advantage of nutritious crops (King 2019). The large mammals have a big appetite that leads to frequent crop raiding in Taita`s communities, especially next to elephant corridors.

Farmers have built fences to keep elephants away from their fields and gardens. However, attracted by the high calorie meals elephants sometimes find a way to breach the physical barriers. Once they enter a closed farm, the animals are trapped, and it is very difficult to chase them away safely without harm or causing further destruction to the fields. Moreover, raising fences around community fields and gardens creates a certain disconnection from the surrounding environment and reinforces the perception that wildlife is in conflict with livelihoods.

How can it be solved ...

The solution at the heart of the Elephant and Bees Project in Sagalla is replacing the physical barriers with permeable boundaries of beehives between farmers and the surrounding land, at the same time creating a new source of income for communities.

Elephants raid crops in the Sagalla area, Kenya
©Jessica Van Fleteren

Langstroth beehive fence line in Tsavo ©Save the Elephants

The idea is simple. Setting up a series of beehives around the fields creates a soft barrier, as elephants are repelled by the buzzing noise of bees in their natural environment and would therefore refrain from coming too close. Experience has shown that the beehives drastically reduced the number of crop raids by 86 per cent. The number of elephants involved during the raids also decreased by over 50 per cent compared with a nearby farm without this protection. Farmers also observed that elephants on the inside of the beehive fences managed to exit through them, indicating that they were not trapped should they end up on the wrong side (King 2010).

In addition to creating more elephant-friendly "fences", the hives ensure that pollinators remain close to the fields, which is beneficial for agricultural productivity. Honey produced by the hives can serve as an additional source of income and is being sold in the region and marketed as "Elephant-Friendly Honey".

Elephant-friendly honey sold by farmers and the Save the Elephants association ©Save the Elephants

However, installing beehives and knowing how to maintain them is an investment that might not be possible for all farmers. To keep costs down, the Elephants and Bees project designed a manual explaining how to build your own beehive from timber or tree stumps that are naturally present around the area (King 2019). Part of the income from the honey supports the installation of new beehive fences and helps households to afford basic goods and services.

The elephants and bees project is implemented by the Save the Elephants association, a charity with headquarters in Nairobi, Kenya. It is supported mostly by donations from individuals and foundations, and as well by selling the honey from the fences. In 2020, the total budget of Save the Elephants was USD 4,188,988.

Who is benefitting ...

The Elephants and Bees project started in 2009 as part of a doctoral research, with just two pilot beehive fences built in the Mwakoma village. With the fences` success and increased enthusiasm among stakeholders, the solution extended to the neighbouring village. In total, 24 farms on the front line of crop raiding events in Sagalla have been protected by 336 beehives. The farms also form the core of the farm-based research accompanying the solution. The Save the Elephants association conducts on-site training and supports projects being developed around Kenya, other African countries and in Asia.

... and how could it work elsewhere?

The beehive fences can be used for farms affected by elephant crop raiding, especially in places where elephants roam freely. In regions where elephant crop-raiding and drought continue to intensify, decreasing local reliance on crop cultivation has the potential to provide greater economic stability (Weinmann, 2018). Beehives have proven effective in different countries of Africa and Asia facing similar human-elephant conflicts. Since the initiative began in Kenya, it has been expanded to Angola, Botswana, Cameroon, Chad, DR Congo, Gabon, Malawi, Mozambique, South Africa, Uganda, the United Republic of Tanzania, Zambia, India, Sri Lanka, Nepal, and Thailand, within and beyond mountainous regions. The single community-based initiatives have been accompanied by research activities for generating data and experiences, scaling up from experiences gained with pilot sites, and provide co-benefits of income generation, biodiversity promotion, and consolidation with wildlife.

Beehives can be established at very little cost using locally found hollowed-out tree trunks. More advanced and productive hives can be built with advanced plywood at a cost of about 35 USD per hive at the time of writing. In comparison, a professional beehive bought from a beekeeping company can cost around 65 USD.

***Jennifer Wanyika Makeo**, project beneficiary in the Mwakoma village, Kenya* ©Save the Elephants

Jennifer has lived in Mwakoma for 20 years and has been battling with elephants since she started her own farm in 2006. Her farm is situated near to the community water pan, making elephant visits common. However, since the arrival of her fence, she feels less vulnerable, because although the elephants will continue to visit the water pan, they rarely manage to enter her farm, giving Jennifer's farm and family increased security from crop raids. Jennifer lives with her daughter and three grandchildren, all of whom are dependent on her farm for food. Often, Jennifer will also work small jobs in the community to raise extra funds. Jennifer has had success producing honey in her hives and appreciates the extra income generated (Elephants and Bees Project n.d.).

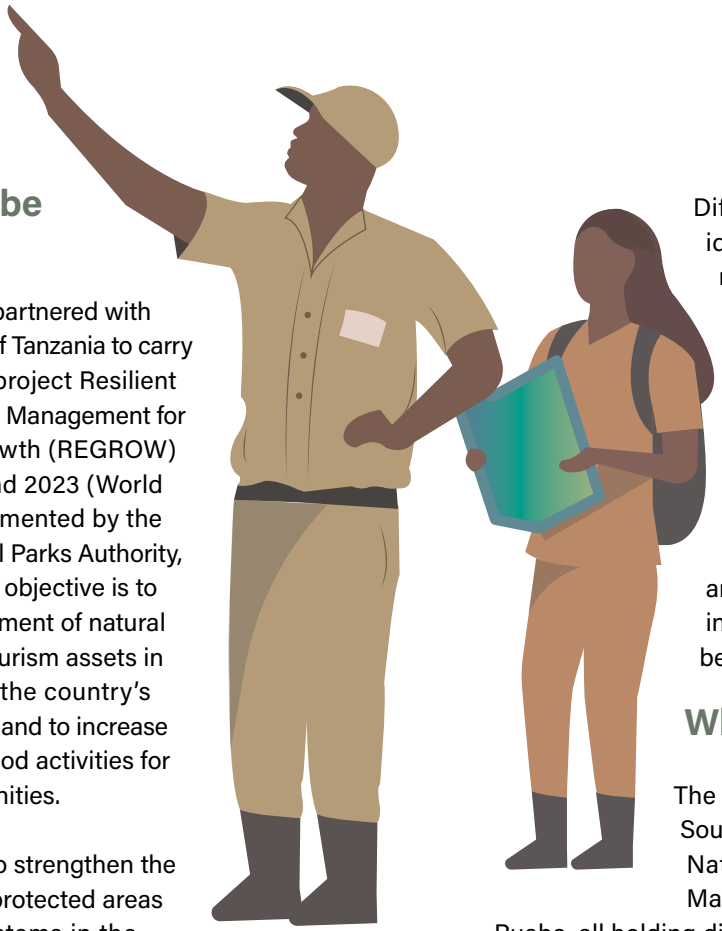
Thrive with ecotourism

What is the issue ...

The effects of climate change are felt across the United Republic of Tanzania, and in the country's South the highlands and Udzungwa mountains are particularly affected. The average temperature is rising, and precipitation becomes increasingly unpredictable. Changes in rainfall patterns have caused severe droughts, which are predicted to intensify. These climate risks greatly impact the ecosystems and ecosystem services on which people's livelihoods depend in the region. The changing climate has multiple effects on the economy, for instance affecting agricultural productivity, energy use, water dynamics, and the wildlife upon which tourism relies. With reduced agricultural production, some people encroach on protected areas to cut down trees for timber and charcoal to earn a living. Other unsustainable practices include poaching and illegal wildlife trade, which contributes to the disappearance of local biodiversity (Mira-Salama 2017). As the country's tourism is predominantly wildlife-based, species loss reduces the attractiveness of the sector. In Tanzania, most tourists visit the North with its landmarks such as Mt Kilimanjaro and the Serengeti. In the so-called "Southern Circuit", which is located south of Dar es Salaam and hosts prominent mountainous national parks such as Raha National Park and Udzungwa National Park, limited infrastructure is another barrier to sustainable development. In order to promote and conserve the natural beauty of mountains, sustainable mountain tourism with improved infrastructure such as visitor centres, logistical services, and roads are required (Romeo et al. 2021).

How can it be solved ...

The World Bank partnered with the government of Tanzania to carry out the six-year project Resilient Natural Resource Management for Tourism and Growth (REGROW) between 2018 and 2023 (World Bank n.d.). Implemented by the Tanzania National Parks Authority, the development objective is to improve management of natural resources and tourism assets in priority areas of the country's Southern Circuit, and to increase access to livelihood activities for selected communities.



REGROW aims to strengthen the conservation of protected areas and their ecosystems in the southern highlands, and provide employment for people living in communities adjacent to these areas. The tourism sector is highly underdeveloped in Southern Tanzania, so a community-based approach is chosen to identify sustainable local income opportunities. Tourism promotion with an emphasis on "Destination Southern Tanzania" includes the development of local tourism programmes and working with groups of households to establish eco-friendly services and supply of agricultural products for tourism operators. This is coupled with training for smallholder farmers to establish conservation-friendly crop and livestock production, hence contributing to preserve the natural environment and reducing human-wildlife conflict.

Different tourist attractions are identified and linked to develop regional branding. To improve access to the national parks of the region, tourist infrastructure such as roads, transport services and visitor amenities are being established.

The communities living in the proximity of the protected areas are given employment opportunities in conservation activities which will be supported by tourism revenues.

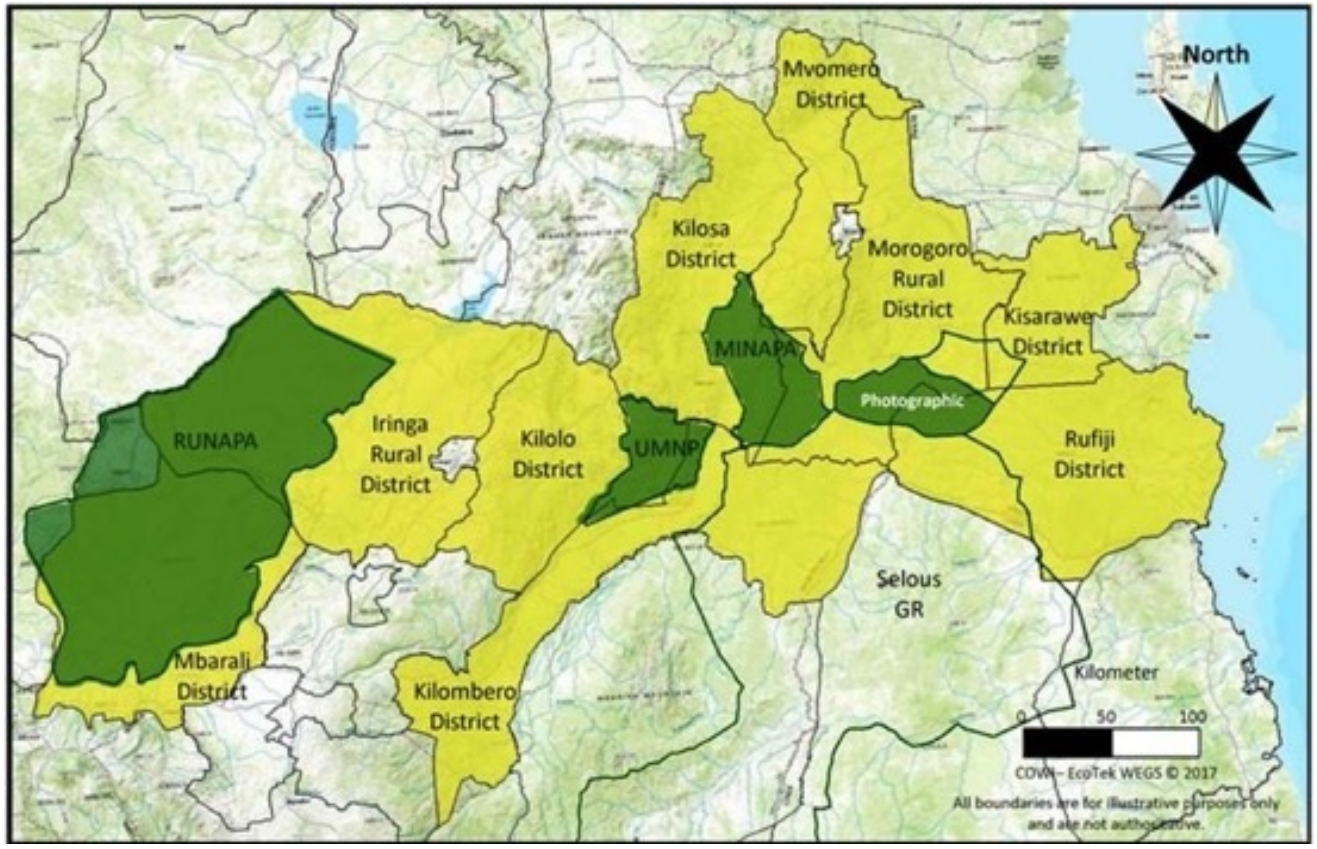
Who is benefitting ...

The project was designed for the Southern Circuit, which includes the National Parks of Katavi, Kitulo, Mahale, Udzungwa, Mikumi, and Ruaha, all holding different tourist attractions. The direct beneficiaries of the project have included around 20,000 households living near the priority protected areas through additional income and economic benefits (United Republic of Tanzania, Ministry of Natural Resources and Tourism 2017) safeguarding their livelihoods in a sustainable way. Sustainable tourism development is interlinked with efforts to promote climate resilience in these key natural asset-based sector with longer-term effects on food security and poverty reduction. The project has a gender-informed approach, with the aim of having women and youth make up at least 65 per cent of beneficiaries (World Bank n.d.).

… and how could it work elsewhere?

Ecotourism has become a prominent element in tourism activities across the world, specifically related to nature and wildlife. Many mountain landscapes in East Africa are rich in biodiversity and can be developed to be tourist destinations. The loss of forest cover on slopes has led to increased vulnerability towards climate risks such as erosion, droughts, and flash floods. Protecting the landscape through ecotourism and alternative livelihoods can improve local communities' and the ecosystems' resilience to climate change (Romeo et al 2021; McAlpine et al. 2018)

The core criteria for ecotourism are nature-based attractions, learning opportunities, and ecological and sociocultural sustainability (Fennell and Weaver 2005). Sustainable and successful tourism development would need to rely on stronger connections with local economies through training and job creation, supply chain development, and other forms of benefit sharing. Conservation-friendly tourism industry can contribute to addressing persistent poverty and support natural resource protection, as park revenue can flow directly back into conservation, and the multiplier effect of tourism spending can grow the local economy (United Republic of Tanzania, Ministry of Natural Resources and Tourism 2017). With the REGROW approach, important success factors include community-based tourism concept development, accompanying training for protected area conservation, and empowering women and youth. The high investment of the World Bank allows for a holistic approach to sustainable mountain tourism with large-scale marketing and infrastructure improvements.



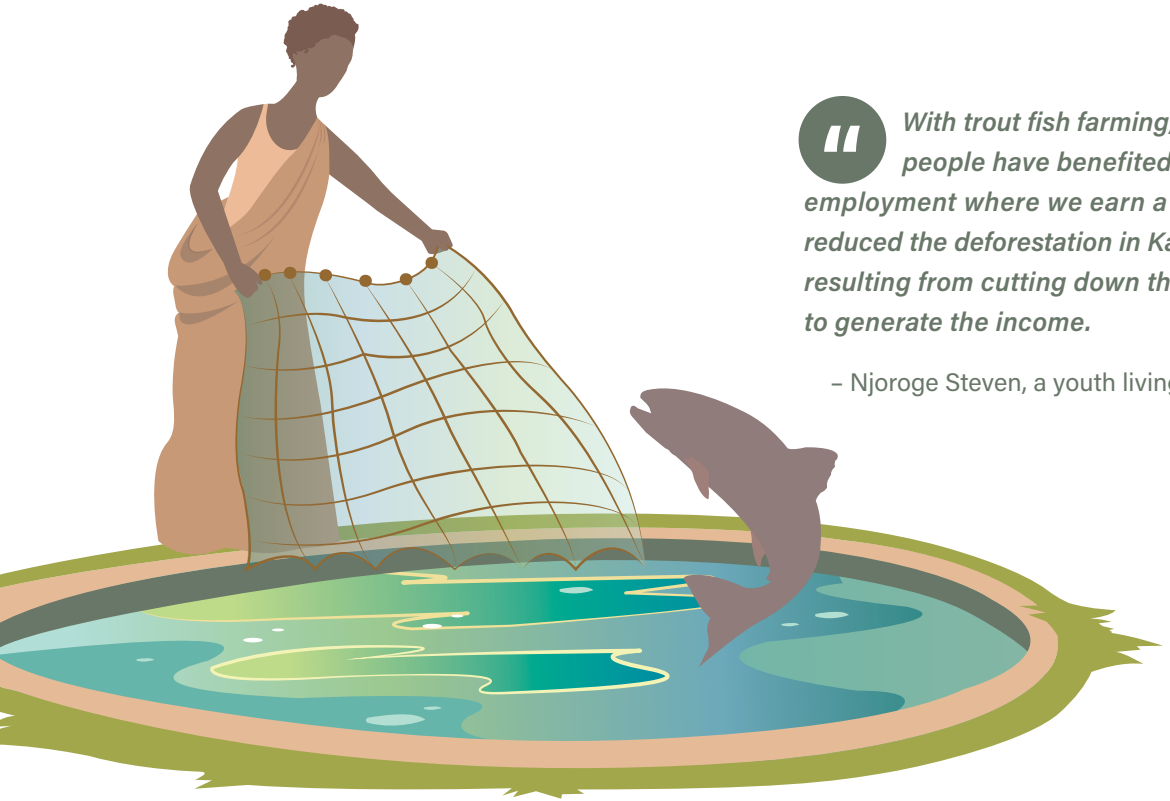
REGROW area ©United Republic of Tanzania, Ministry of Natural Resources and Tourism

Fish for future

What is the issue ...

Mount Kenya is with 5,199 masl the highest mountain in Kenya and the second highest on the African continent. Although the mountain is just under 16 kilometres south of the equator, small glaciers can still be found around the summit. However, the mountain is already suffering the effects of climate change and has witnessed an immense reduction in its ice cover. According to the World Meteorological Organization (2021), all remaining African glaciers are likely to disappear within the next three decades. This, coupled with changing precipitation and higher temperatures, causes problems for communities settled downstream, as they experience a general reduction in high run-off flows with only seasonal peaks. Fluctuation in water supply can severely affect mountain and downstream communities, where many rely on an agricultural livelihood (Dell'Angelo et al. 2014). The reduced water availability poses a threat to the local livelihoods due to reduced agricultural output and creates conflicts over resources between people living in the lowlands and those upstream.

Youth are among the most vulnerable social groups to climate change in the region and many no longer find crop farming a viable livelihood option. Leaving the mountain areas to seek opportunities in urban centres has been popular among youth, however, employment may also be limited in the cities. Of the young people who decide to stay in mountain villages, some resort to cutting down trees for commercial charcoal burning, contributing to deforestation.



> *"With trout fish farming, most of us young people have benefited through getting employment where we earn a living. This has reduced the deforestation in Kabaru forest that was resulting from cutting down the trees for charcoal to generate the income.*
>
> – Njoroge Steven, a youth living in Nyeri, Kenya

How can it be solved ...

In an attempt to address the lack of viable livelihood options for youth, the local self-help group Jitunze Environmental Group (JEG), which originally consisted of some 20 young people, started trout fish farming on the slopes of Mount Kenya (Nyamai 2020). The group first came together in 2004 to create their own fish farms as an adaptation solution to the challenging and changing circumstances. They learned about the fish farming business through a peer, who had participated in leadership training in the USA. Following the idea consolidation, JEG raised sufficient funds and obtained the required permits from the Department of Fisheries. The funds came from several sources, including family support and labouring on farms. The first trout fishpond was completed in 2008.

With 505,440 Kenyan Shillings (approximately USD 4,500) the JEG constructed three ponds, cemented them, built a small hatchery, installed water pipes and bought their initial stock of 500 fish from a state-owned trout farm (Nyamai 2020). By 2015, the group had seen their number of ponds increase to 18 due to increased revenue resulting from high demand for trout.

The water used in the ponds runs back to the river for reuse, meaning that trout fish farming does not have a negative impact on the water access for other usages. JEG has in

addition contributed to revitalizing forests by supporting the planting of 100,000 trees in the Mount Kenya region (Equator Initiative n.d.). The trees provide shade and affect the microclimate, hence ensuring that the ponds stay at the required cooled temperatures (Nyamai 2020). The mountain forest further filters air and water and stores much-needed water (Makino and Rudolf-Miklau 2021).

Trout fish farming is a rather novel business in the region. As trout is in high demand compared with other breeds such as tilapia or African catfish, for which Kenya offers a large market (Nyamai 2020). This opportunity for youth to generate income has also reduced the outmigration of young people from the mountain communities to urban areas.

In addition to the profit from selling fingerlings (juvenile trout) and fish, the farms have also become a tourist attraction and receive an average of 2,500 visitors each year, including students, researchers and international visitors (Nyamai 2020).

Showcasing a fish farm to visitors ©Jitunze Environmental Group (JEG)

Who is benefitting ...

At the time of writing, the self-help group has 26 members, of which 11 are male and 15 are female. The fish farming takes place on the slopes of Mount Kenya in the communities of Kyeni, Kabaru and Nyeri. As of 2016, around 101 beneficiaries along the value chain benefited from this alternative livelihood option, being able to earn an income, which in turn has reduced the need for cutting down trees to sell charcoal in the region (Equator Initiative n.d.). The beneficiaries include the business members, labourers and those involved in training activities. The number of community members trained annually has increased from 2,000 to 3,000 (Equator Initiative n.d.).

... and how could it work elsewhere?

Trout farming requires knowledge of the species, as well as keen monitoring as trout is demanding compared to other breeds. Applying this solution elsewhere therefore requires training and initial investment covering the construction of ponds and other infrastructure needed for the fish farm. The solution is well suited to a high elevation mountain climate, as trout farms require cold temperatures of 13°C. Members of the JEG are trying to scale their initiative and train up to 3,000 people annually through visits to their farm (Equator Initiative n.d.). Additional benefits include the marketable product, increased awareness for water use and empowerment of youth in the local communities.

Buzz-boosting techniques

What is the issue ...

Udzungwa Mountains National Park is part of the Eastern Arc Mountains, which stretches from Taita Hills in Southern Kenya to the Makambako Gap in central Tanzania. The park is known for its high biodiversity of plants and animals with a high density of endemic species. The park's mountains serve as a water tower for communities in the region and many agricultural livelihoods rely on this water source. Still, the park's natural resources are under pressure through poaching, unsustainable timber harvesting and cutting down trees for cooking fuel (Eastern Arc Mountains Conservation Endowment Fund [EAMCEF] 2013). Driven by a lack of alternative sources of livelihood, these activities are further enhanced by the effects of climate change, such as unreliable rainfall. The warmer temperatures, decrease in precipitation and increased incidence of crop pests and diseases affects the agricultural productivity, causing the communities to turn to forest resources for supplementing and sustaining their livelihoods.

The Eastern Arc Mountains Conservation Endowment Fund (EAMCEF) is a permanent and long-term funding mechanism created to provide sufficient and reliable funding for effective conservation of the Eastern Arc Mountains. The EAMCEF was established in 2001 as a joint initiative of the Tanzanian government, the World Bank and Global Environment Facility (GEF) and currently operates as a non-profit trust. It was established with the aim of addressing the need for a long-term funding scheme for biodiversity conservation in the Eastern Arc Mountains. It funds a variety of projects, some of which support local groups in diversifying income sources and incentivize locals to refrain from unsustainable practices. The EAMCEF identified beekeeping as one potential alternative livelihood for rural communities living adjacent to protected areas of the Udzungwa Mountains National Park. Modern beekeeping increases pollination of wild and agricultural plants, provides income, and may help conserve the forest cover. The EAMCEF therefore started a series of beekeeping projects in 2012 in the districts of Korogwe, Mkinga, Lushoto, Same, Morogoro, Kilombero, Mvomero, Kilolo and Mufindi (EAMCEF n.d.).

Prior to this initiative, a group of ten farmers agreed to form a beekeeping group named 'Wosia wa Baba.' The group gathered 10 beehives, locally made from logs, and hanged them in the protected forest. Each beehive produced only 5 litres of honey per year. The beekeepers also used fire to chase the bees when harvesting honey. With this technique, fire is left uncontrolled and could ignite nearby trees or spread even further into the forest, potentially causing forest fires. The forest authority in the area prohibited such activities and put strong measures to prevent people from invading the forests. The group therefore chose a small area within the village and decided to plant trees for beekeeping, but still this was not economically viable. Furthermore, the honey was unprocessed due to the lack of proper equipment, and therefore generated only low prices on the market (EAMCEF n.d.).

How can it be solved ...

To make beekeeping a profitable business and conserve and restore protected forests in the Udzungwa Mountains, EAMCEF provided members of the communities adjacent to the park with modern beehives to replace the traditional ones and offered training in modern beekeeping skills. The beekeepers were also encouraged to carry out tree planting for forest and biodiversity restoration which also contributes to increased water retention in the soils of mountain forests.

With EAMCEF support, members of the communities adjacent to the protected area have embraced beekeeping as an alternative source of livelihood, and unsustainable activities, such as cutting down trees, have been reduced. Instead, community members now use part of their land near the park to plant trees as a way of conserving the environment, as well as to hold the beehives.

Modern beehives supplied to beekeepers ©Eastern Arc Mountains Conservation (EAMCEF)

> ***We were using traditional hives, but they were less productive. A beehive would produce about 5 litres of honey in a year, a modern beehive produces 20 litres or more in a harvesting season.***
>
> – Zawadi Mercy, beekeeper in Sanje village, Tanzania

Who is benefitting ...

With financial support from the EAMCEF, the modern beekeeping initiative started in 2012 with 15 million Tanzanian Shillings (USD 9,375) to provide an alternative source of livelihood and incentivize communities to stop encroaching on the protected areas.

A total of 1,570 villagers have been trained in modern beekeeping techniques. Over 82 beekeeping groups have been formed to take care of 1,352 modern beehives.

The beekeeping groups generate two types of products: honey and beeswax. Since the inception of the project in 2012, it is estimated that over 14,180 litres of honey have been harvested annually and 508 kilograms of beeswax collected, creating a sales revenue of 7,6647,400 Tanzanian Shillings, which is equivalent to about USD 33,000 (EAMCEF n.d.). Some groups in the Sanje village have reinvested the revenue from selling honey, for example to buy bicycles that are rented out as means of transport. In this way, beekeeping has spurred further business opportunities.

... and how could it work elsewhere?

Several communities in East Africa carry out small-scale beekeeping, using traditional knowledge and locally made hives. By mobilizing community members in groups and teaching modern ways of beekeeping through peer-to-peer learning, the solution is scalable to other areas. An important part of the solution is a long-term sustainable funding mechanism, such as the EAMCEF, to support the transition to modern techniques that are protecting natural resources and fostering sustainable livelihoods.

Go eco-village

What is the issue ...

The East Usambara Mountains in north-eastern Tanzania are famous for their forests being rich in biodiversity. The region is also home to villages of small-scale farmers, practicing rain-fed agriculture. This means they are dependent on the stability of the yearly two rainy seasons. However, precipitation patterns are changing, driven by local forest degradation and global climate change, which is leading to increased frequency and intensity of both droughts and floods (Gaworek-Michalczenia, Sallu and Di Gregorio 2019). In the Muheza district, the Zigi River, which communities rely on as a source of water for domestic use and agriculture, is also experiencing significant variations in water flow. This has implications on the communities as their water demand cannot be met during seasons with reduced flow.

There are further socioeconomic and managerial challenges limiting the capacity to adopt climate change measures in the East Usambara Mountains. These include lack of financial resources, farmers not receiving sufficient information like weather forecasts, ineffective communication between government entities, and climate change not being prioritized in local government development strategies (Pilato, Sallu and Gaworek-Michalczenia 2018).

> *"Participation of women in development issues and in making decisions in the village has increased, which is positive. In the VSLAs groups, women decide by themselves how to use the money, no one is telling a woman to do something.*
>
> – Halima Sheshe Idd, acting chairperson, Mvambo village

How can it be solved ...

Between 2015 and 2019, the European Union funded the "Integrated Approaches for Climate Change Adaptation in the East Usambara Mountains" project, under the Global Climate Change Alliance. The project adopted the eco-village approach to increase and diversify incomes, strengthen resilience and reduce vulnerability to climate change (Wella 2018). The eco-village approach builds on a holistic idea of sustainable development, where a mix of interventions, such as new farming practices and building local governmental adaptation capacity, are implemented to achieve the social, environmental and economic dimensions of sustainability at the community level (Yuliastuti et al. 2017).

Empowering women has been a central element of the solution

The solution has had a strong focus on education, particularly on training farmers in climate-smart agriculture (CSA) techniques. To adapt to a drier climate, the promoted techniques included digging water trenches to contain more rainwater and planting new drought-resistant crops. Lessons learned, however, showed that attention should not exclusively be on drought for CSA.

Climate projections for the East Usambara mountains suggest that while consecutive rainy days may decrease, increases in extreme rainfall events are highly probable and already being observed with substantial negative impacts on villagers' livelihoods including failure of drought-resistant crops. Thus, adapting agricultures practices overall needs to factor in a broader range of possible climate futures and a more flexible approach for decision-making (Gaworek-Michalczenia, Sallu and Di Gregorio 2019).

To adapt to the warming temperatures, farmers were also taught to plant black pepper. While this spice has not been feasible to grow in the cooler mountain environments until recently, it can now be farmed as a valuable cash crop due to the changing climate.

Measures were also introduced to improve ecological resilience. This included a bylaw limiting farming close to the river and water spring to protect these sources and improve the water quality for downstream communities. While this measure is ecologically sound, a review of the project found that the prohibition undermined economic opportunities for upstream communities, resulting in lower community cooperation (Gaworek-Michalczenia, Sallu and Di Gregorio 2019). A lesson learned was therefore to identify and pursue linkages between ecological

resilience and livelihood opportunities, and the need to compensate farmers or find alternatives if measures negatively impact their income opportunities.

The eco-village approach further has an institutional dimension, where building capacity with communities and the local administration plays a key role in ensuring sustainability of the solution. In this project, water management committees and forest co-management were developed to overcome institutional weaknesses.

Since climate change impacts in the region have been linked to local forest degradation, finding ways to combat this degradation was an important part of the eco-village strategy. Good governance initiatives and better collaboration were promoted by identifying cross-sectoral opportunities for district departments through workshops and joint planning exercises. Community leaders participated in these workshops, improving their capacity in local environmental planning, and increasing government accountability.

Farmer working in the field ©Global Climate Change Alliance Plus/European Union

To address the economic dimension of sustainability, loans and saving associations were developed. A Village Savings and Loan Association (VSLA) is where a group of people meet regularly to deposit money together. These savings are then fed into a loan fund owned by the group, from which members can borrow small amounts. Women were among the key beneficiaries of this initiative.

Who is benefitting ...

The eco-village approach was implemented in eight communities located near high biodiversity forests in the East Usambara Mountains. The many achievements of the project include 27 farmer groups equipped with CSA techniques, the establishment of participatory forest management in five villages and the establishment of water management committees to manage the use of water from the river and springs. Lastly, more than 400 people received access to financial services for adaptation solutions through the VSLAs.

... and how could it work elsewhere?

Eco-village approaches require the involvement of many stakeholders, which can be a barrier for uptake in smaller mountain communities. However, as a solution it provides a holistic approach to climate change adaptation, and can target the climatic, environmental and socioeconomic concerns found in mountain communities across the region and beyond. Main success factors of an eco-village in mountains includes the ownership of local decision-makers, training of climate-smart agricultural practice and raising awareness for the local mountain environment and biodiversity.

SOLUTIONS

Water harvesting and retention

Climate change at higher elevations is more pronounced than the global average, particularly precipitation patterns vary more at altitude, both in quantity and frequency (IPCC 2021). Several factors impact the weather systems in East Africa, including the Intertropical Convergence Zone (ITCZ). This is a zone of heavy precipitation, where the north-east and south-east trade winds meet. The zone moves northward and southward depending on the season, influencing the precipitation patterns. Climate change is altering the position of the ITCZ, which has a changing effect on rainfall and hence the food production in the region (Mamalakis et al. 2021).

East African mountain ecosystems are highly productive agricultural areas supporting large populations. However, observed and future climate change effects increase the frequency and intensity of droughts in some regions, lowering animal growth rates and productivity in pastoral systems and leading to negative effects in food security. Like in other mountain ranges, East African glaciers are shrinking and are now at less than 20 per cent of their early twentieth century extent (World Meteorological Organization 2021). Glacier retreat is changing the amount and seasonality of water runoff with local impacts on water resources and agriculture (IPCC 2019). This affects communities like those on the hillsides of Mount Kenya, which have used meltwater for their crops and livestock (Prinz et al. 2018).

Fresh water as a natural resource is becoming increasingly in need of attention, even in tropical regions where previously water was abundant. The solutions presented in this section target the existing and predicted difficulties with water resources under a changing climate. Agricultural production can benefit from more efficient irrigation infrastructure, contributing in turn to better use of resources. Diverse tools, from new technologies, such as geographic information system (GIS)-based planning, to traditional knowledge, can create solutions to better manage water resources. Improving management and cooperation is essential when implementing small- and large-scale solutions to ensure sustainable and fair distribution of water resources to the local populations.

Put rain to use

What is the issue ...

The challenges facing the Virunga area in Uganda, Rwanda and the Democratic Republic of the Congo are largely related to water supply, including watershed degradation due to soil erosion and communities fetching water from within the national parks and reserves of the Virungas. The temperatures in this region could rise 1.4ºC compared to pre-industrial levels by 2040 and there are concerns that human-wildlife conflict could increase as temperatures and water shortages drive farmers to encroach on the resources in protected areas (United Nations Environmental Programme [UNEP] 2020).

For instance, in the town of Kisoro, Uganda, the local population has faced serious water access challenges, which led to outmigration to the vicinity of the national park, where the local population has free access to good quality water from within the park. The Mgahinga Gorilla National Park is well known for its mountain gorillas, and the conflict potential between the gorillas and the people living in the communities nearby has increased (UNEP 2020). These conflicts include gorillas invading people's farms and destroying the crops, and people harming the gorillas in defense.

A community rainwater harvesting water tank under construction in Nzogera village ©Water for Virungas (W4V)

How can it be solved ...

In Uganda, the Water for Virungas Project (W4V) developed the Kisoro Virunga Water Supply Extension, which aims to reduce human-wildlife conflict through increased access to safe water and improved watershed management in the transboundary Virunga area. The project was implemented under the framework of the Greater Virunga Transboundary Collaboration and promoted collective action at different levels, targeting communities that interact with natural resources of the national parks. W4V ensured the direct involvement of citizens and the local governments to address conflicts that emerged between people and wildlife.

Harvesting of rainwater became a central part of W4V´s solution and rainwater harvesting tanks (RWHT) were supplied to villages. The tanks included water catchment roofs and collection chambers, and the increase of water harvest surface and storage size improve villages` water security in the face of scarcity (Kisakye, Akurut and Van der Bruggen 2018). Pumping stations related to the RWHT were upgraded to increase their capacity, and public stand posts were constructed in villages along the park with a distribution line network of 31.2 km. The solution thus includes a set of infrastructure improvements to increase the community's access to clean water.

On the management side, water sanitation committees were established in the targeted villages. A total of 96 committee members including community leaders were trained in the operation and maintenance of water harvesting infrastructure. The training also included topics such as national park conservation, sanitation and hygiene, safe water chains, conflict resolution, and effective communication. The trainings targeted about 50 per cent women, and sought to include Batwas, a marginalized indigenous group.

Who is benefitting ...

The project was implemented in 16 villages in the three parishes of Gitenderi and Rukongi in the Nyarusiza subcounty and the Gisozi parish in the Muramba subcounty. 12 RWHT of 30 m^3 were constructed in a total of 10 villages neighbouring the Mgahinga Gorilla National Park. In Nyarusiza, a 58,000-litre water tank received an upgraded pumping station, capable of pumping 40,000 litres per hour compared to the previous 10,000 litres per hour capacity. The Gasiza booster stations' 58,000 litre tanks were also upgraded from 10,000 litres per hour to 30,000 litres per hour pumping capacity.

The interventions increased productivity in the communities in terms of time saved from fetching water from far distances, especially for women who carry most of the domestic work burden. This is a result of increased availability, accessibility, and affordability of safe water and water governance. Relations between communities and the park authorities improved as the people have gained access to water outside the protected areas, leading to reduced human wildlife conflicts in the communities.

A water tank in Kabande village ©Water for Virungas (W4V)

... and how could it work elsewhere?

The solution´s approach can be applied in other mountain regions in a similar way. However, it requires significant resources in terms of funds and human capital that involves local communities, local government and development partners, all with different capabilities. The use of RWHT for domestic use is not widespread in Uganda, and upscaling these systems has been mentioned as an important solution for improving water security in the country (Staddon et al. 2018). Further success factors for the uptake of RWHT and local good water governance include training, fostering awareness for local wildlife protection as well as providing income opportunities, e.g. through water infrastructure maintenance and agricultural irrigation.

> ***"The people of Kisoro near the park now have access to clean water near their homes and no longer go to the protected areas to fetch water. The project has also improved their livelihoods as they have home gardens which are the reliable source of their food and sometimes income after selling the surplus.***
>
> – Halima Sheshe Idd, acting chairperson, Mvambo village

Guiding water flows

What is the issue ...

Bulambuli and Kween are two parishes located along the Atari River, which is part of a river basin located to the north of Mount Elgon in eastern Uganda. In these parishes, 77.8 per cent of people farm as a primary occupation (Japan International Cooperation Agency [JICA] 2017), many of whom rely heavily on rain-fed agriculture and livestock farming. Droughts and floods are the biggest problem faced by farmers in and around the slopes of Mount Elgon, followed by poor farming methods, deforestation, and soil erosion. During the dry seasons, the evapotranspiration rate is high due to steady winds and lower humidity, leading to water stress and low agricultural productivity. This situation is exacerbated by poorly planned irrigation schemes along the Atari River, which divert uncontrolled amounts of water into the fields. With more unstable fluctuation in precipitation and more extreme drought and flood events projected as a result of climate change, these stressors will increase. In addition, there are also conflicts over unequal access to water resources, pointing towards insufficient regional and local water management.

How can it be solved ...

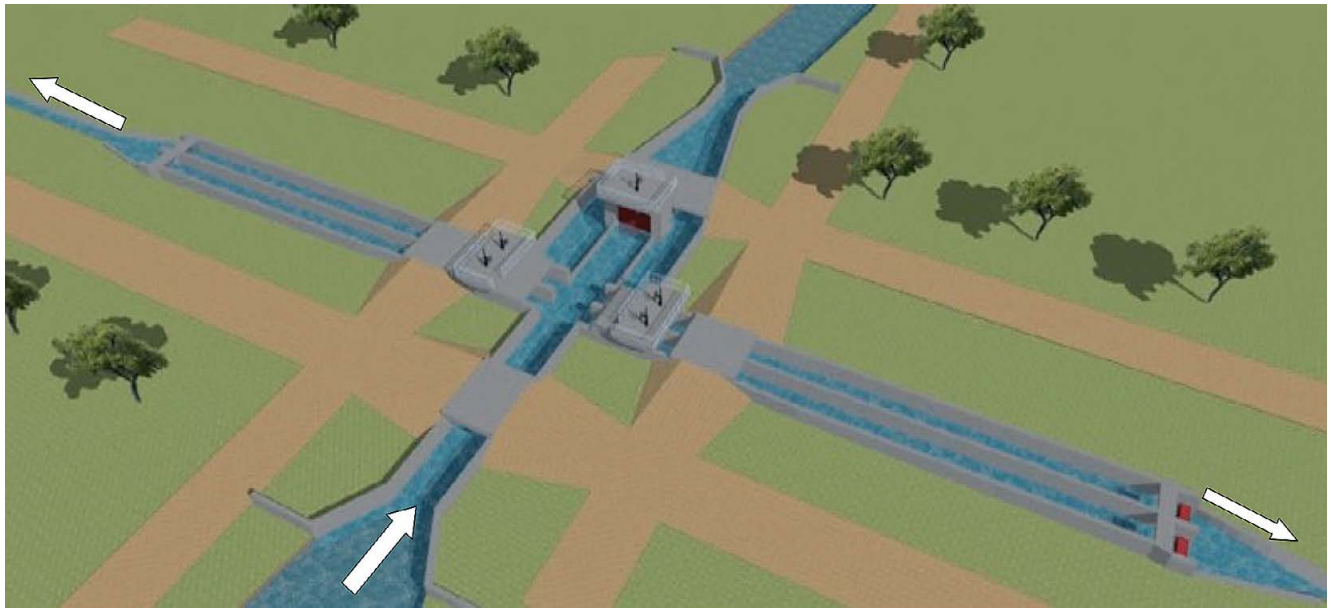
In 2018, the Ugandan Ministry of Agriculture, Animal Industry and Fisheries acquired a grant of over 93 billion Ugandan Shillings (approx. USD 26 million) from the Japan International Cooperation Agency (JICA) to establish irrigation systems in the Atari basin area. In addition to improving the socioeconomic situation of local farmers, the project has also sought to eliminate existing conflicts among the resource users and reduce the problems related to droughts and floods through a fair distribution of water. For this, the Atari River has been readjusted to its original river course which also reduced the extent of encroachment in the downstream Ramsar site[6] (JICA 2017).

Rice farmers have been the main target group of the project. Therefore, a thorough understanding of existing farming practices and their primary pressures have been important. The project surveys found large differences in production between areas that struggled with unstable water conditions and areas with existing irrigation systems. Rice growers themselves identified the lack of irrigation as the biggest constraint to farming (JICA 2017). A main goal of the solution therefore has been to secure farmers steady access to clean water for irrigation purposes, which included head works and canals.

The irrigation system consists of head works that contain diversion weirs with gates, a spillway and fishway, and intake structure equipped with gates. The width of the diversion is wide enough to flush out flood discharge when the gates are fully opened. The gates are manually operated and made of steel work that is reinforced with concrete. The spillway is located at the diversion weir to avoid frequent adjustment of the intake water level, which happens when gates are opened or closed. On the farms, the system consists of main canals, secondary canals and tertiary canals for irrigation. The main canal is also designed and constructed to collect run-off water (JICA 2017).

[6] A Ramsar site is a wetland designated to be of international importance.

Implementation of new technologies, such as irrigation schemes, can radically alter the social structures into which they are introduced. One way the solution has addressed this concern is by forming a close cooperation between dispatched experts and local officials to develop a good understanding of the socio-economic context and to ensure the sustainability of the project after implementation. The establishment of a functional management structure for the irrigation system is central to long-term sustainability, including water users' associations (WUAs), which play a central role. These associations consist of various water stakeholders and serve as an arena for discussion and negotiation to ensure equal access to water. For example, in dry years, negotiations are needed with farmers along the river to coordinate the irrigation and cropping calendar, and therefore reduce conflict between upstream and downstream actors (JICA 2017).



Head works at Atari Site ©Japan International Cooperation Agency (JICA)

Who is benefitting ...

The project aims to benefit approximately 532 households in the two parishes of Bulambuli and Kween. With more access to reliable water for farming, the farmers have increased their production, which has improved food security and their livelihoods through the income generated. The goal of the scheme is to increase the yearly rice production by 5,000 tons (Fatiah 2018) to help local farmers improve their income and overall increase Uganda's food self-sufficiency. Through the irrigation scheme, the rice farmers can adapt to changing climatic conditions and continue with rice growing activities while improving water use efficiency.

... and how could it work elsewhere?

The Atari Irrigation Scheme is a large and costly adaptation solution consisting of a thorough preliminary study and including several elements that target different sectors. The irrigation system itself requires expensive investment in the respective infrastructure. The solution also requires technical training of personnel and farmers, as well as training in management and cooperation between stakeholders. Implementation of a solution of this scale is therefore only applicable when large investments are obtained. However, the approach also contains elements and concepts, such as the arrangement of WUAs, that can inspire solutions with less funding. The preliminary studies, environmental assessments, and consideration of the socioeconomic contexts are all prerequisites for successful adaptation solutions with regards to water management. The irrigation intervention has been adopted in other areas of the Elgon region; for example, the Ngenge Irrigation Scheme at Ngenge River currently supports the farmers in Kween under the Ministry of Water and Environment's Farm Income Enhancement and Forestry Conservation Programme.

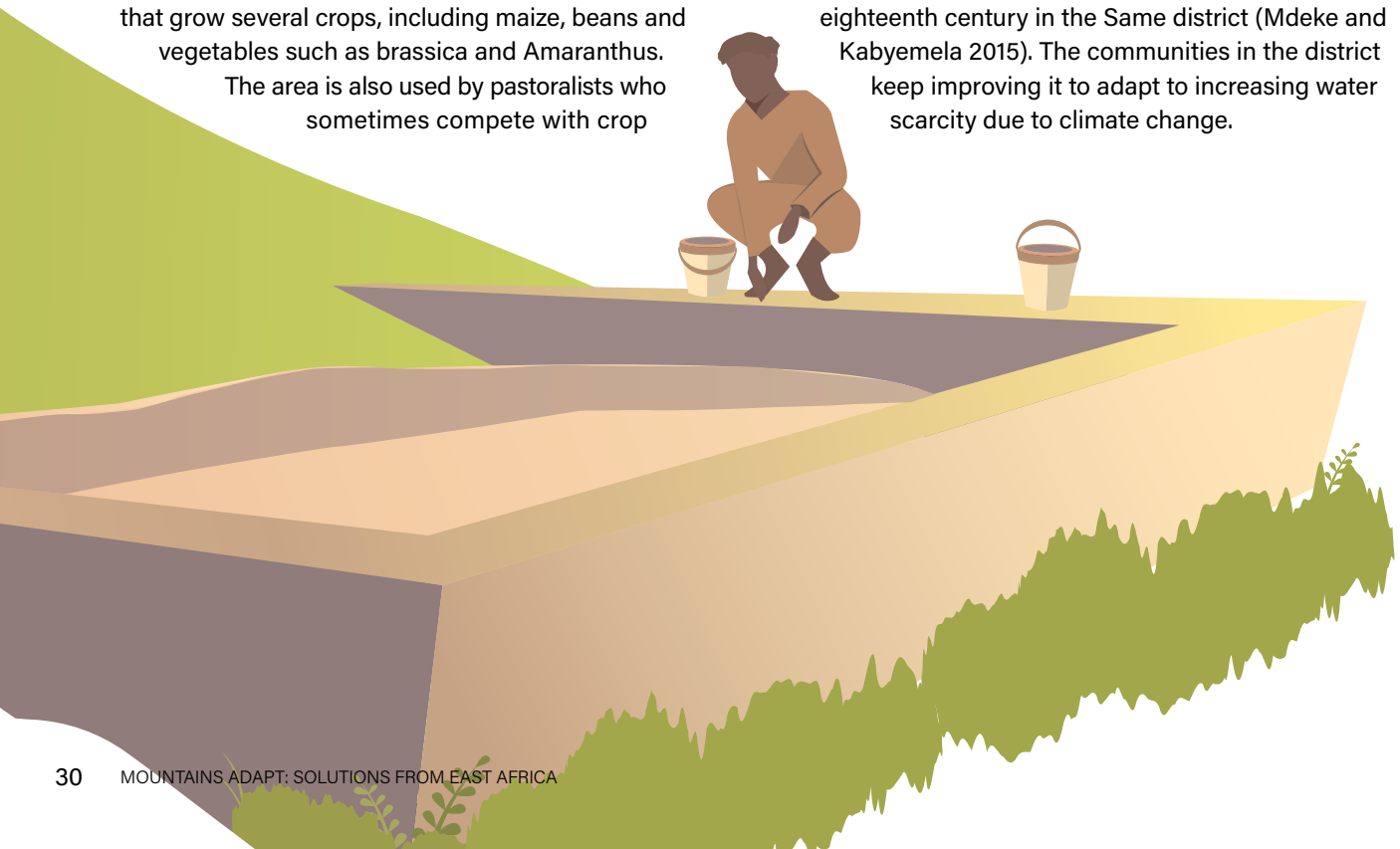
Trust traditional *ndivas*

What is the issue ...

Most farmers in the United Republic of Tanzania have traditionally relied on rain-fed agriculture, which can be a problem when rainfall is unreliable or provides insufficient water to farms. Water scarcity caused by frequent dry spells, coupled with an increasing demand for water resources due to a rapidly growing population, is particularly challenging in the highland areas of the Kilimanjaro region. Climate change is increasing the unpredictability of precipitation patterns, thus causing a further concern for smallholder farmers (Afifi, Liwenga and Kwezi 2014; Tomalka et al. 2020). One area affected is the Same district south-east of Mt Kilimanjaro, which consists of agrarian communities that grow several crops, including maize, beans and vegetables such as brassica and Amaranthus. The area is also used by pastoralists who sometimes compete with crop farmers over water. This competition can end in conflict between the two groups due to scarcity of water resources. Faced with water challenges, farmers in these communities have revisited old techniques to respond to contemporary issues.

How can it be solved ...

In the Same district, located in the Makanya catchment, farmers have resorted to a traditional irrigation technique known as *ndiva. Ndiva* is a local word that means micro dam, and community members build these micro dams to harvest water for irrigating their farms during dry spells. This water harvesting technology is based on traditional knowledge and has been used since the eighteenth century in the Same district (Mdeke and Kabyemela 2015). The communities in the district keep improving it to adapt to increasing water scarcity due to climate change.



A *ndiva* is constructed by excavating the soil to create a reservoir of the desired size. The micro dams vary in size depending on many factors including the size of the farms to irrigate, the number of farmers that will use the reservoir and the human capacities available. These human-made water reservoirs normally range from 200 m^3 to 1,600 m^3 (Mul et al. 2011). The *ndivas* are located close to the farms on a raised area where they can collect rain and spring water. The natural slopes of hill and mountains sides allow the water to flow through conveyance canals to the fields and gardens. In some cases, concrete is used as material to build the reservoirs. On average, the canals can carry water to crops over a distance of 500 meters but can also reach 3,000 meters (Snelder et al. 2018). A challenge is water loss occurring through seepage when the water travels over longer distances. To address this issue, the farmers have created stone pavements in the canal.

The *ndiva* system can store water during dry spells and serve more than one farm. Some community members in Same have established their irrigation system as a group. As the system is relatively easy to manage, working collectively is a viable opportunity to share the workload. In a group-owned system, the members water their fields and gardens taking turns, hence increasing overall productivity and improving food security (Nicol et al. 2015).

The community groups are solely responsible for the *ndiva* system in terms of construction and maintenance. The local governments make contributions through the district agricultural development plans to support the communities, but largely the groups in the communities organize themselves to cover for the investments needed by providing own labour.

Who is benefitting ...

With the *ndiva* system, the farmers in the communities have been able to increase crop productivity. For example, maize production has increased seasonally from an average half ton to about 2 tons per acre. With increased production, community members enjoy better food security and improved earnings from crop farming (Snelder et al. 2018). Working in groups also strengthens solidarity within the communities. The solution has also reduced conflict between the crop farmers and the cattle keepers, which previously resulted from competition over scarce water resources. Lastly, the piped system of *ndiva* have led to less use of plastic canisters and bottles for water, hence reducing resource consumption and waste (Ikeno 2018).

Constructed ndiva supported with concrete ©Hans Komakech

> ***"We have been able to sustain our gardens during the dry seasons because of the ndiva system. It has helped many farmers witness higher productivity from their crops to feed their families.***
>
> – Musa Mzumbwe, a farmer in the Makanya village, Same district

... and how could it work elsewhere?

The *ndiva* system can easily be applied in other mountain areas as it is adapted to collect running water in steep terrain (Snelder et al. 2018). The expenses of such a system can also be reduced if farmers organize themselves in groups and contribute with labour to construct the micro dams and jointly undertake maintenance. It is also important that the farmers plan for watering their gardens on a rotational basis, as water may not be sufficient for all of them at the same time.

Getting slopes in shape

What is the issue ...

The Sebeya river is located in Rwanda`s Western Province. On its 110-kilometre-journey from the mountains in the Rutsiro district to its final destination in Lake Kivu, the river runs through steep, mountainous terrain, which has historically seen heavy rainfall events. However, due to climate change and population pressure, floods and erosion have increased. This is particularly the case in areas where deforestation, unsustainable agricultural practices and mining is taking place. These challenges are exacerbated by only few economic opportunities, a lack of alternative sources for livelihoods and limited access to markets.

The districts of Rutsiro, Ngororero, Nyabihu and Rubavu are located along the Sebeya river, and have all witnessed devastation caused by the floods from the river. Steep mountainous landscapes, fragile soils and intensive use of limited land resources coupled with unsustainable agricultural practices make the entire watershed catchment area of the Sebeya river highly vulnerable to climate change.

60-year-old farmer, Nyirakadari Colette, resident of the Arusha village in Nyabihu district received a water tank

How can it be solved ...

Embedding Integrated Water Resource Management in Rwanda (EWMR) is a three-year project that started in 2019, which targets erosion control and flood risk reduction in the four districts of Rubavu, Rutsiro, Ngororero and Nyabihu. The project is implemented by the Rwanda Water Resource Board and supported by IUCN, the Rwanda Rural Rehabilitation Initiative and the SNV Netherlands Development Organization (IUCN n.d. a).

EWMR uses a participatory approach to include local communities for undertaking landscape restoration and fostering improvement of natural resource management. Working with the communities from the onset shall strengthen ownership and contribute to the project's sustainability in the long term. It is important to work with existing farming cooperatives to implement adaptation solutions, such as crop rotation, planting tree species favoured by farmers on their cropland, using organic manure, and other climate smart agriculture (CSA) practices. CSA involves growing crops such as Irish potatoes, tomatoes, onions, carrots, cabbage, white eggplants, avocado, and sweet bananas.

The farmers have also been supported to build small dams and construction channels that regulate the water flow and help irrigation in their gardens, as well as terraces (IUCN, n.d. a). Using terracing for growing crops

decrease erosion as well as the input of upstream water into the Sebeya river, reducing the river's peak level and confining the damage during flood events. By retaining more precipitation, the soil becomes richer in terms of soil nutrients and water availability for the crops grown on the slopes. The communities have also been involved in tree planting activities to address the issue of deforestation through agroforestry.

The holistic approach has also provided water harvesting tanks to communities that have limited access to water for domestic use (IUCN n.d. a). Local gender roles often give women the responsibility of fetching water, a task that requires travelling long distances. With the provision of water reservoirs, this task will become less strenuous. Women have also been able to establish home gardens, which they irrigate using the water collected.

Another element of EWMR is improving the water management information system. In doing so, the project is contributing technical innovations that can be applied in other catchments in the country (IUCN n.d. b).

Who is benefitting ...

The EWMR project follows an integrated Ecosystem-based Adaptation (EbA) approach combining adaptation solution elements that altogether provide benefits for livelihoods in the community through improved income and food security. There are also conservation benefits in the catchment area, leading to flood and erosion control. At the end of 2020, IUCN reported that the EWMR project had reached 100 communities through its participatory community approach. With the flood risk mitigation activities, the EWMR project has already created more than 8,000 jobs for smallholder farmers in the Rubavu district, who have been involved in tree planting for reforestation. Over 107 farmers have been involved in the CSA activities.

During the challenging times of COVID-19, which affected the economy and livelihoods of many citizens, 15,000 local people had an income through the project, working on restoration activities. The project is planned to run until end of 2022 and has restored almost 3,000 hectares of land to date (IUCN n.d. c).

... and how could it work elsewhere?

Rwanda is known as the "land of a thousand hills" and over 70 per cent of its population are involved in agriculture, highlighting the applicability of these solutions in other areas of the country. Similar solutions have already been replicated in other catchments such as Mukungwa and Akagera (IUCN n.d. d). The introduced water management information system is for example a technical innovation developed which can be adopted across the country. The focus on EbA and achieving several co-benefits such as the reduction of flood risk, increasing crop resilience and empowering women have proven successful with this integrated approach.

> ***"I am excited that my family is benefiting from the project, we get enough food from our garden as we are no longer affected by the floods that used to destroy our crops. We have also benefited from the income generated from the paid labour.***
>
> – Maria Ndayishimiye, a resident in the Nyabihu district, Rwanda

Manage your catchment

What is the issue ...

The Imatong Mountains are located in south-eastern South Sudan, in the Eastern Equatoria region. These mountains and the neighbouring areas are experiencing climate change effects manifested through prolonged periods of severe drought and water shortages. This greatly affects the economic activities of the communities that rely on natural resources for their livelihoods. Due to unsustainable practices such as deforestation, land degradation and poor cultivation on hillsides, the Kenneti watershed has seen heavy soil erosion and pollution of the river. This in turn has threatened the lives of the communities whose water supply is interlinked with the watershed and the ecosystem's wildlife populations.

Dry spells have increased the competition for water resources between crop farmers and pastoralists, leading to conflict between these groups. On the other hand, during the rainy seasons, floods have caused damage to many farmers' crops. Historical political tensions in the country further reduce the adaptive capacity of the communities in Imatong Mountains.

> ***"The project shows that resilience programming can work. For a long time, the people of South Sudan have only received relief aid, which does not allow them to develop new skills to improve their living environment. Despite difficult circumstances in the past, project beneficiaries have shown a yearning to shape their own future. And understandably so, as restoring self-reliance gives people a sense of dignity and control over their lives.***
>
> – Marc Mazairac, First Secretary, Development Cooperation, Embassy of the Kingdom of the Netherlands, South Sudan

How can it be solved ...

The Water for Eastern Equatoria (W4EE) project, implemented from 2013–2019, developed an integrated water resource management in the Kenneti catchment that was conflict-sensitive, climate-resilient and contributed to different local sectors (NIRAS n.d. a.). It created a holistic approach to water management that satisfied the needs of several groups. Water access has been improved for farmers so they can water their crops during droughts and supply pastoralists with water for their animals. W4EE introduced structures for collaboration and as a result reduced the conflict between groups relying on the same water resources.

New communal water points ©Water for Eastern Equatoria (W4EE)

To develop resilience in the targeted communities, the project established sustainable water infrastructure such as subsurface dams, put in place small water distribution systems and rehabilitated dilapidated water points. Additionally, farmers received equipment such as treadle water pumps to enhance their crop farming during the dry seasons. This has improved the farmers' ability to withstand pressure from climate change, promoted household food security and enabled them to generate an income from selling the surplus they produced. Pastoralists also have improved access to water for their cattle thanks to the extension of water distribution points. Finding and collecting water is often part of women´s tasks in this region and going out searching for water left many women at risk of violence. With the new infrastructure installed, also women´s security has been improved.

The backbone of the solution is the institutional structure of the integrated water resource management of the Kenneti catchment and the surrounding areas. To ensure longevity of the measures and the water resource plans, the project collaborated closely with actors in the local community as well as government officials and established groups to institutionalize functional local water management. Those local water management committees were supported with training in management, operation, and maintenance of the infrastructure. Each household now contributes to the

Farmers showing off crops ©Water for Eastern Equatoria (W4EE)

pool of funds set up to pay for repairs and other services (NIRAS n.d. a).

The catchment was divided into sub-catchments, with each being managed by different water users' associations (WUAs) residing in their respective sub-catchment. These associations consist of interest groups such as farmers and pastoralists, collaborating with local authorities.

The Kenneti Watershed Management Board was established and a new technology introduced with a decision-support system called the Mike Hydro model, and GIS to map the upper, middle and lower watershed areas to identify potential agroecological, hydrological and production zones (NIRAS n.d. a).

Overall, the catchment management has been based on an inclusive structure where the interests of different groups can be discussed and taken into consideration.

Who is benefitting ...

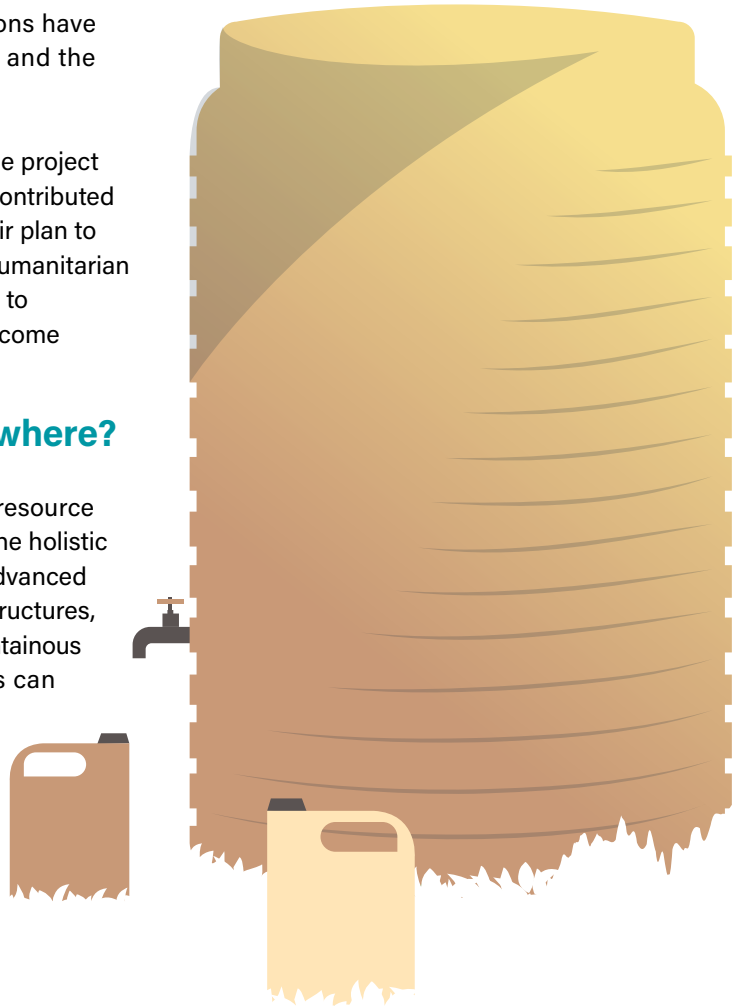
The project estimates to have benefited approx. 220,000 people by providing access to clean water. The W4EE constructed 91 new water points and rehabilitated 106 existing ones (NIRAS n.d. b). The interventions have improved household income, food security and the standards of living in the area.

The close involvement of the community in the project established local ownership, which strongly contributed to the success. The stakeholders adapted their plan to have quick-impact interventions to address humanitarian crisis issues, particularly by seeking solutions to the insufficient food production and lack of income opportunities for residents (NIRAS n.d. b).

... and how could it work elsewhere?

W4EE served as a pilot for integrated water resource management programmes in South Sudan. The holistic approach, from the creation and training of advanced GIS systems to building local management structures, can inspire adaptation solutions in other mountainous areas of developing countries. GIS systems can provide solutions, as they target climate-related risks found in hilly landscapes. Building sustainable governance structures that enable collaboration between groups and governments at different levels can help mitigate upstream-downstream conflict, also when facing climate change induced water scarcity.

Another key factor for sustaining success of this approach is raised awareness and capacity among the local population and government authorities for the need of integrated water resource management that addresses clean water supply holistically as part of the broader ecosystem (NIRAS n.d. a).



SOLUTIONS | Renewable energy

Creating sustainable energy systems is a key element for the world to mitigate climate change and reduce greenhouse gas emissions. This is also true for mountain communities in East African countries, a region with one of the lowest electrification rates in the world, with less than a quarter of the population having access to electricity (Gordon 2018).

Mountain communities are mostly settled in remote areas and have limited infrastructure; electricity is therefore often not a viable energy alternative. Rather, firewood and other biofuels are important energy sources, especially for cooking. As a regenerative source of energy, firewood can be a renewable source if managed sustainably. However, overconsumption of local resources is a major concern in many mountainous regions in East Africa, where the population pressure is high. Combined with natural hazards such as floods, erosion, and landslides, that are increasingly exacerbated by climate change (IPCC 2021), this overconsumption raises the vulnerability for many mountain communities.

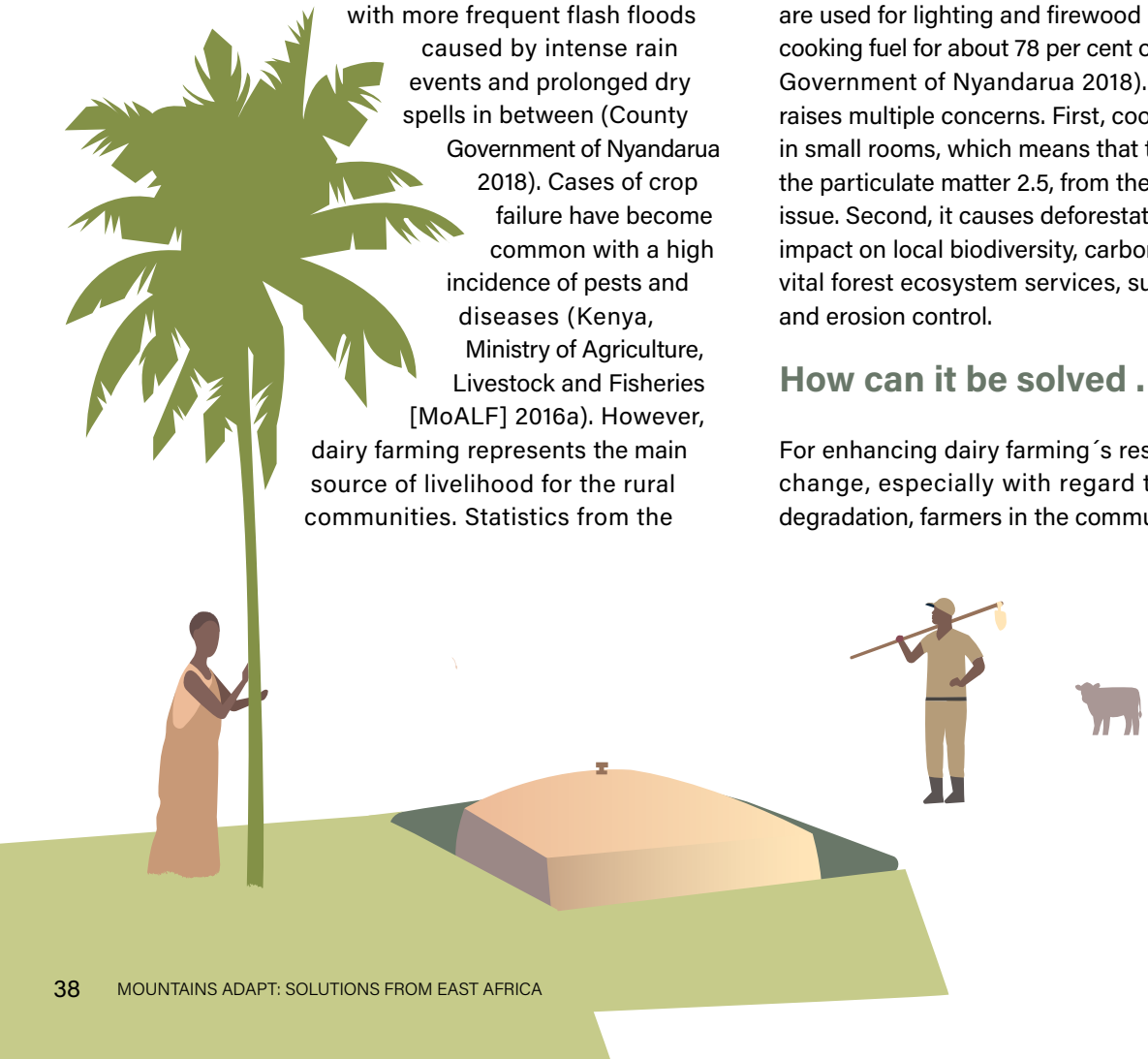
The excessive use of firewood also creates multiple concerns in terms of emissions, apart from emitting greenhouse gases. When used for indoor cooking, the emissions from burning wood cause health issues, which is particularly problematic for women who are most often responsible for preparing meals. Furthermore, cutting down forests for firewood reduces their overall capacity as carbons sinks, limits essential ecosystem services such as air and water purification, and further heightens exposure to natural hazards (Wassie and Adaramola 2019).

Finding alternative ways to cover growing energy needs therefore has the potential to create multiple benefits, including increasing adaptive capacity, reducing greenhouse gas emissions, and empowering women. There are many opportunities for adopting small-scale renewable energy sources in the region that improve health and address climate change concerns (Wassie and Adaramola 2019). The innovative solution showcased below introduces circular energy creation and ways to generate energy from a source already found in many communities.

Cow dung for fuel

What is the issue ...

The Nyandarua county is located in central Kenya, just north of the capital Nairobi. The county is home to the Aberdare Range, with beautiful valleys and striking waterfalls. While rainfall previously was common throughout the year, with a change in climate the county is now facing two distinct rainy seasons with more frequent flash floods caused by intense rain events and prolonged dry spells in between (County Government of Nyandarua 2018). Cases of crop failure have become common with a high incidence of pests and diseases (Kenya, Ministry of Agriculture, Livestock and Fisheries [MoALF] 2016a). However, dairy farming represents the main source of livelihood for the rural communities. Statistics from the county government show 80 per cent of Nyandarua's families farm and 65 per cent of households are involved in dairy farming, an activity that also faces a high risk of reduced productivity resulting from current and future climate-related hazards.



Especially in the mountainous, remote areas of the county, electricity is not widely available. Mostly lanterns are used for lighting and firewood is the most common cooking fuel for about 78 per cent of households (County Government of Nyandarua 2018). The use of firewood raises multiple concerns. First, cooking often takes place in small rooms, which means that the smoke, especially the particulate matter 2.5, from the fire is a major health issue. Second, it causes deforestation, having a negative impact on local biodiversity, carbon sequestration and vital forest ecosystem services, such as water storage and erosion control.

How can it be solved ...

For enhancing dairy farming´s resilience to climate change, especially with regard to land and soil degradation, farmers in the communities moved from range management of livestock to a zero-grazing system, where cattle are kept in small structures near their homes and are provided with fodder to ensure its availability throughout dry periods. Many households feed their cattle with silage, grass, hay and concentrate supplements. On average, a household has five to six cows, and this small-scale system can easily be managed.

In addition to generating revenue from milk, zero grazing also presents a new opportunity for the households in terms of generating energy for cooking, lighting, and even producing electricity. The installation of small-scale biodigesters that turn organic matter such as collected cow dung into biogas, represents a great substitute for the use of firewood. A biodigester is a sealed tank, in which anaerobic degradation of the organic substance generates biogas. This process also creates a slurry as a by-product that can be used as fertilisers for crop farming, thus enriching the soil on farmlands. With only two cows in zero-grazing one can provide sufficient feedstock to qualify for a biodigester (Kenya Biogas Programme n.d.).

Through the Kenya Climate Smart Agriculture Project, the Ministry of Interior and Coordination and the Ministry of Livestock have provided training and extended services to farmers of Nyandarua county to reduce pressure on the already fragile environment. Project components have included assistance in installing household biogas systems, which use cow dung to create an alternative energy source for cooking.

The cost of a biogas system is 80,000 to 100,000 Kenyan Shillings (USD 880). Some parts of the biodigester itself are installed underground. To cut costs, households often provide labour by excavating

the area where the digester is installed. Properly collecting and processing cow dung creates enough biogas for a household to cut its fuel cost almost in half (Ngotho 2021).

Who is benefitting ...

In promoting the use of biogas among households across Kenya, the Ministry of Energy, supported by the Dutch Government, commenced implementation of the Biogas Programme in 2009. Since then, a total of 20,000 biogas plants have been installed (Kenya Institute for Public Policy Research and Analysis 2020). The project is planned to be extended to Nyandarua's neighbouring counties of Nyeri and Taita-Taveta, and the plan is to reach 5,000 households in the three counties by 2022 (Ngotho 2021).

The farmers in Nyandarua who own biodigesters have been able to stop using firewood in their kitchens. This not only helps the families to reduce their daily workload, but improves their respiratory health due to reduced indoor pollution. Due to the existing gender roles, this reduction is most beneficial for women and girls in rural settings, as they are mostly responsible for cooking and collecting charcoal and firewood.

Reducing the use of firewood through installing biodigesters has even more benefits. One biodigester can reduce up to the equivalent of 13.1 tons of carbon dioxide and prevent deforestation leading to 1.08 tons of carbon sequestered per year (Ngotho 2021). Apart from offering a source of clean energy suitable for cooking, lightning, and electricity generation, anaerobic digestion, even at the small-scale, also represents an efficient waste treatment and improves sanitation through reduced water pollution (Pilloni and Hamed 2021).

... and how could it work elsewhere?

There are about 50 million rural household digesters already operating in China, India and other parts of Asia, Africa and South America. These primarily run on livestock manure and the biogas produced is used domestically for cooking and heating, substituting firewood, charcoal and other solid biomass. However, this only taps into just 1.6-2.2 per cent of the global potential of anaerobic digestion with an extraordinary potential for growth (World Biogas Association 2019).

Rural communities in more isolated geographies such as mountain areas without proper energy supply infrastructure can particularly benefit from access to digesters to make circular use of their organic waste in generating household biogas. The solution requires an initial investment and training in applying the biodigester. In addition, some farming techniques, such as zero grazing, are more suited for biogas production than others. Therefore, an assessment of local conditions and opportunities should be conducted to calculate the local potential. Important enabling factors for biodigesters include a sound cost-benefit analysis, local ownership of the farming community, sustainable funding such as through carbon offsets, and maintenance of the technology.

> *"Our dairy farm of six cows has helped us to generate family income from selling milk but we also use the cow dung to generate biogas for cooking. The biogas system is very effective and reliable, we no longer need charcoal or firewood.*
>
> – James Mureithi, farmer in the Nyandarua county

SOLUTIONS | Ecosystem restoration

Land degradation refers to the long-term reduction in the biological productivity and ecological integrity of ecosystems. The causes of land degradation stem, directly or indirectly, from human activities, including anthropogenic climate change, soil erosion and unsustainable land use (Olsson et al. 2019). Degradation of mountain ecosystems is endangering crop production, animal husbandry (Romeo et al. 2020) and overall food security. East Africa's hilly and mountainous regions are subject to deforestation and heavy land-use pressure, particularly from agriculture. The areas are prone to soil instability, erosion, landslides and flooding, which is accentuated in hilly terrain. With the projected climate effects of heavy precipitation events, droughts and warmer temperatures, mountain landscapes will be further exposed to land degradation if countermeasures are not taken (Wei et al. 2018). Ecosystem restoration is defined as "assisting in the recovery of ecosystems that have been degraded or destroyed, as well as conserving the ecosystems that are still intact" (United Nations Decade on Ecosystem Restoration 2021). Several global initiatives seek to spur ecosystem restoration efforts, including the United Nations Decade on Ecosystem Restoration from 2021-2030 and the Bonn Challenge. In Africa, the African Forest Landscape Restoration Initiative (AFR100) aims to restore 100 million hectares of land across the continent by 2030. Under this initiative, all the EAC countries covered in this booklet, except for South Sudan, have committed to restoring a total of 26.6 million hectares of land (AFR100 2021; Mansourian and Berrahmouni 2021). In 2018, the Pan-African Action Agenda on Ecosystem Restoration for Increased Resilience was supported at the Seventh Special Session of the African Ministerial Conference on the Environment (AMCEN). This agenda proposes policy measures, strategic actions, cooperation mechanisms and on-the-ground actions to advance land and ecosystem restoration in Africa.

The overarching goal of ecosystem restoration efforts is to restore ecosystems to host richer biodiversity, contain more fertile soils, produce higher yields of renewable resources, and sequester larger amounts of carbon, while also helping people adapt to the impacts of climate change (United Nations Decade on Ecosystem Restoration 2021). Inclusive participation is key for achieving the desired outcomes of restoration over the long term and should be promoted as much as possible throughout the process, from planning to monitoring. This includes ensuring a key role for local communities in decision-making, recognizing rights, needs and concerns, especially of under-represented groups (e.g., Indigenous peoples, women, youth), with the aim to provide effective incentives to improve livelihoods, and offer fair and equitable distribution of benefits (FAO, IUCN CEM and SER 2021). The most recent IPCC Sixth Assessment Report Working Group II report on Impacts, Adaptation and Vulnerability (IPCC 2022; Adler et al. 2022) highlights the importance of conservation, protection and restoration of terrestrial ecosystems together with targeted management to adapt to climate change impacts. It has become clear that the resilience of communities and ecosystems increases with size of the natural area and restoration of degraded land. Restoration further supports services provided by mountain ecosystems and reduces pollution and other stressors. Activities such as afforestation and river renaturation widely mitigate mountain related natural hazard risks. The adaptation solution featured below provides insights into how ecosystem restoration has been implemented in Rwanda to combat land degradation in the mountains.

Restore with silvopastoralism

What is the issue ...

The Gishwati-Mukura National Park is located in Rwanda's Western Province, near the border with the Democratic Republic of the Congo. Gishwati and Mukura are two nearby forests that together span several districts. They were originally designated as forest conservation zones and therefore protected from human activities. However, the 19 km stretch of hills between the two remaining reserves have faced high population pressure, and people have encroached on the protected areas to retrieve resources. This has led to unsustainable activities such as deforestation, extensive animal husbandry in previous protected areas, and illegal mining leaving unfixed open pits. As a result, the Gishwati mountain range and Mukara forest had experienced the highest rate of deforestation in Rwanda. In 2009, the US National Aeronautics and Space Association (NASA) released parallel satellite images of the Gishwati Forest area from 1986 and 2001, revealing that in the 15 years that elapsed between these images, only a small circular patch of 600 ha remained of the forest's original 101,000 ha (US National Aeronautics and Space Association [NASA] 2009). The loss of the forest cover had severe environmental consequences such as accelerated soil erosion and landslides. This is exacerbated by cultivation on steep slopes and the fragile volcanic soil of the region. Current climate variations are increasing the stress on the natural resources which are already overused by the dense population surrounding the reserves. This, together with the unpredictable weather patterns associated with climate change, has further reduced agricultural productivity (World Bank Group 2014).

> *"We used to collect firewood inside the park and take our animals there for grazing. We did not know the importance of a park, we thought it was like any other forest. Now, thanks to the improvements we are witnessing in communities living near the park and various trainings, we decided to protect the park instead of encroaching on its habitat. Now it is well protected.*
>
> – Rose Mukarulinda, resident in the Rutsiro district

How can it be solved ...

To tackle the issue, the Rwanda Environment Management Authority (REMA) started implementing the five-year project Landscape Approach to Forest Restoration and Conservation (LAFREC) in 2015. The main financial support has come from the Global Environment Facility (GEF) and – as of 2017 – the Nordic Development Fund (NDF), through the World Bank.

LAFREC is built on a landscape approach, which is an integral and holistic line of action that spans social, economic and environmental fields to mitigate trade-offs between different human and environmental needs (Sayer et al. 2013). In total 40,000 ha, covering the former Gishwati Forest Reserve, Mukura Forest and the in-between corridor, were to be restored to a single protected area (World Bank Group 2014).

Activities focused on four primary aspects to bring the forest ecosystems into better management and develop multiple benefits, which included (1) supporting agroforestry and rehabilitating forests and biodiversity within the Gishwati and Mukura Forest Reserves; (2) establishing silvopastoralism in the rangelands of the central former Gishwati Reserve; (3) carrying out participatory sustainable land management planning with local communities; and (4) harmonizing land use planning for the Gishwati landscape (World Bank Group 2014).

Rehabilitating the area and enhancing biological connectivity at the landscape level offered the potential for global recognition as a UNESCO Biosphere Reserve along with longer-term re-orientation of the local economy towards nature-based tourism and contributing to livelihoods diversification.

The wider project contained a plethora of activities to achieve ecosystem restoration, however, the introduction of silvopastoralism has been particularly interesting. Silvopastoralism is an agroforestry farming technique that sees agriculture as part of a larger ecosystem, emphasizing the use of native species. It is a tree-based livestock system, where trees, shrubs and other vegetation planted on pasturelands provide fodder, and the goal is to create multiple benefits for farming, animals and the natural environment (Chará et al. 2019). It enables farmers to have paddocks for their farms and this way better control the grazing patterns.

Within the rangeland areas of the former Gishwati Forest Reserve, the introduction of silvopastoral techniques included planting and managed natural regrowth of trees on ridge-tops and extreme slopes, functioning as live fences, shelter belts and providing shade for crops. In addition to enhancing forest cover and biological connectivity, these techniques boost overall farm productivity of rangelands by protecting against land degradation and provide shelter for animals during the dry season and from climatic extremes. Some species, such as Sesbania sesban, Cytisus proliferus

and Leucaena leucocephala, can be used as fodder for the cattle and goats. This form of agriculture has not been common in Rwanda, and its results are therefore important to follow to see if it brings merit and can be implemented in other regions (REMA 2021).

Furthermore, fences have been established around the Gishwati-Mukura National Park to stop uncontrolled human entry into the protected area and hinder the farmers' cattle from grazing in the park. With reduced human interference, ecosystems will have time to slowly restore. Significant steps were also made in improving the park infrastructure, for instance by creating a visitor centre and guard posts for the Rwanda Development Board (REMA 2021).

Silvopastoral interventions have also been accompanied with capacity-building for already established farmer groups and cooperatives, as well as training on improved livestock and pasture management, initial inputs (e.g. seed) and tools in support of specific livelihood improvements, which included consideration of the local women´s role as vital members of both landscape management and climate resilience efforts (World Bank Group 2014).

Who is benefitting ...

Since its inception in 2015, the project has been implemented in the Rubavu, Rutsiro, Nyabihu and Ngororero districts. After six years of implementation, LAFREC ended in September 2021 with several achievements towards strengthening climate resilience for the population in and around the Gishwati-Mukura National Park. 3,214.5 ha were rehabilitated using sustainable land management investments where the incorporation of native tree species was emphasized. Thereof, 446 ha were restored under silvopastoralism through supporting farmers to manage natural regeneration of their pasturelands (Siborurema 2021).

Overall, rehabilitation was done through participatory planning with local communities. 40,482 household members directly benefited from the project interventions whereby 53 per cent were female. For additionally improving local livelihoods, the farmers received 91 cows, 104 pigs, 720 goats and 3,011 sheep. 25 park rangers and guides were recruited and trained (Siborurema 2021).

In 2020, UNESCO granted the Gishwati-Mukura landscape Biosphere Reserve status, illustrating the project's accomplishments (World Bank 2020a).

Steep hill pastures for silvopastoralism ©Rwanda Environment Management Authority (REMA)

... and how could it work elsewhere?

This type of large-scale project implemented at the landscape level always has unique elements and must be tailored to local socio-economic contexts. Uniting nature with environmental restoration, e.g., through silvopastoralism, provides an important adaptation solution for other mountainous communities in the region. Local communities have provided positive feedback with regards to additional environmental benefits, such as a reduced risk of erosion and shorter ways for livestock to access water and shade. This is relevant for mountain communities practicing animal grazing. Important success factors have been the lead of a competent national authority, a holistic approach to adaptation, and sufficient funding.

SOLUTIONS

Climate-smart agriculture and agroforestry

Almost 80 per cent of people living in the EAC Partner States are dependent on an agricultural livelihood, and the sector mostly consists of smallholder farmers (East African Community [EAC] 2020). This sector has great potential to increase production, but also faces risks from climate change. Farmers at high altitudes have adapted their crops and harvest cycle to the existing climate regime, however with warming temperatures and changing precipitation patterns their systems may no longer be suitable. Population pressure and degraded land further increase the vulnerability of farmers, making them more prone to natural hazards like erosion and landslides. The vulnerability is directly linked to regional food security, meaning that climate change impacts are a human and societal concern.

While there are multiple future stressors for agriculture in East African mountain communities, there are also adaptation solutions that can produce multiple benefits. Climate-smart agriculture (CSA) and agroforestry are two central concepts when it comes to adaptation solutions for this sector.

CSA is an approach that helps guide actions to transform agri-food systems towards green and climate resilient practices. It aims to sustainably increase agricultural productivity and incomes; adapt and build resilience to climate change; and mitigate greenhouse gas emissions and pressure on local environments (FAO 2021a). Agroforestry is one example of CSA which collectively stands for a dynamic, natural resource management system that either integrates trees on farms and in agricultural landscapes or introduces agricultural products in forests. Agroforestry has been practiced as a traditional approach to cultivation in varying forms across the world and in Africa (FAO 2022). By integrating perennial trees in agriculture systems, it is possible to create multiple adaptation benefits, such as improved soil fertility, reduced erosion risk, better protection against landslides, and lee from strong winds (Mbow et al. 2014; Hairiah et al. 2020). Local biodiversity also improves as agroforestry creates a more varied agricultural landscape with increased species variability and richness, contributing to enhanced ecosystem services (Udawatta et al. 2019). Studies have found that agroforestry, if done right, contributes to higher yields through improved soil fertility, thus enhancing food security and contributing to more diverse livelihoods (Agroforestry Network 2018).

While CSA offers available and affordable adaptation solutions, it requires structural transition in agriculture practices, that link local knowledge with area-specific effects of climate change. Fostering capacity building through training and information sharing and increased collaboration, plays a key role in enhancing resilience of farmers' livelihoods. The following mountain adaptation solutions highlight the risks and enabling factors of implemented approaches and can serve as a source of inspiration to expand CSA to other mountain communities.

The power of peer learning

What is the issue ...

Burundi's highlands are affected by environmental degradation and climate change impacts that have caused poor crop and livestock productivity, loss of ecosystem services, and loss of agrobiodiversity. An increase in rainfall, heat, and extreme weather events are examples of changing climate patterns that affect Burundi's development efforts. These changes manifest as repeated floods and droughts, which can have devastating consequences for agricultural and animal production, leading to decreased food security, leading to decreased food security and soil erosion which pollutes water resources, and potentially cause loss of life (Burundi, Ministry of Environment, Agriculture and Livestock 2019). It is estimated that as many as 85 per cent of households in Burundi suffer from daily food insecurity (Resilient Food Systems [RFS] 2019).

The north-western district of Bubanza is facing severe erosion, which greatly affects farming on the steep slopes that shape this part of Burundi. The communities predominantly depend on rain-fed subsistence agriculture as a source of food and livelihood where a decline in agricultural production due to prolonged droughts is further contributing to food shortages, rural-urban migration, and increased vulnerability to climate change (RFS 2019).

> *"With the help of Farmer Field Schools, we have been able to control soil erosion through the use of contour lines and planting of trees. In the previous seasons, most of the crops were affected but with these techniques, productivity has increased.*
>
> – Margaret Nimbona, a farmer in the Musigati commune, Burundi

How can it be solved ...

Support for Sustainable Food Production and Enhancement of Food Security and Climate Resilience in Burundi's Highlands has been a large-scale project engaging partners at the national, provincial, and communal levels in Burundi through Global Environment Facility (GEF)'s Resilient Food Systems (RFS) programme. The Food and Agriculture Organization of the United Nations (FAO) has been implementing the project in collaboration with the Burundian Ministry of Agriculture and Livestock as the lead government counterpart and coordinating agency, in close collaboration with the Ministry of Water, Environment, Land Management and Urban Planning. Together with farmers in the north-western highlands of the country, RFS reduces the climate change vulnerability in the region by adopting more climate-resilient practices in the agricultural sector and improving the production systems and increasing food and nutrition security for the region's inhabitants. An integrated natural resource management (INRM) approach was adopted. This includes working across the food production value chain to increase its sustainability.

INRM is a holistic approach that increases agrobiodiversity and diversifies food production systems (RFS 2019). A particularly successful solution has been the establishment of Farmer Field Schools (FFS) to train farmers in land and water conservation techniques (RFS 2019). FFS provide a platform for smallholder famers to come together to exchange information, test practices, and co-create innovations. The FFS is best described as "Schools without walls" for which usually one farmer (the host) in the group offers land for use as the field school. Through peer-to-peer learning and being in the fields, farmers gain practical skills that allow to transition to more sustainable farming practices (FAO 2021b). In a community participatory approach, FFS open the dialogue between different stakeholders and can be used for putting scientific knowledge into practice. FFS have also been shown to strengthen gender equality by empowering women with skills for diversified income opportunities and by creating more equal relations between genders through collective action (Chocholata 2020). In this regard, the training sessions provide a platform for female farmers to connect, exchange knowledge, experiences and resources, discuss the needs of the community and devise solutions collectively (RSF 2021).

The FFS have focused extensively on agroforestry, a diversifying practice that combines perennial trees and farming to create biodiverse agriculture ecosystems. In addition to benefiting agrobiodiversity, it is particularly effective in steep landscapes as it reduces erosion by protecting both surface and subsurface soil. A pertinent agroforestry practice includes contour planting, where contour lines of different vegetative bush and tree barriers are planted across slopes to prevent soil movement and improve water retention. With the use of this technique, farmers have seen an increase in crop productivity (RFS 2019). The increase in production of food crops such as maize and beans due to reduced erosion has enabled the farmers to improve their food security and economic livelihoods.

In the communities around the Kayokwe, Mubarazi, and Ruvyironza rivers, planting bamboo trees has been effective in addressing soil erosion and reducing landslide risk.

Culm-segment cuttings have grown bamboo seedlings from the stems of existing plants. The bamboo trees protect the riverbanks and help improve water quality by decreasing sedimentation and reducing pollution.

Who is benefitting ...

The project has established 105 FFS in 58 communes, enabling the farmers to control erosion and adopt agroforestry practices. A total of 1,987 households, 69 per cent of which are female-led, have benefited from the interventions (RFS 2020).

Based on the successes of this approach, the Burundian government has decided to institutionalise FFSs by using it as part of its toolbox within national extension service plans and strategies for providing technical support to the country's farmers (RFS 2020).

The FFS have diverse members ©Food and Agriculture Organization of the United Nations (FAO)

In the Musigati commune of the Bubanza Province in north-western Burundi, farmers established over 12,541 metres of contour lines installing 16,617 plants, most of which were calliandra plants. By August 2021, 8,500 hectares of degraded land have been restored and 20 kilometres of riverbanks were stabilized through planting bamboo.

Updates on achievements from the 2021 country roundtable confirm that this approach promotes self-help, social cohesion, and diversification of community livelihoods. The 43 FFSs in Burundi have now been structured into 16 operational cooperatives further promoting local ownership and ensuring sustainability for increasing climate change resilience in the communities (RFS 2021).

... and how could it work elsewhere?

The solution has focused on community participation, which allows farmers to take an active role and contribute to the success of FFS. It is common in the East African region for farmers to organize themselves in groups, making this solution viable in other mountain communities in the region. Important supporting factors for applying FFS elsewhere include rural development strategies and services in the communities, an inclusive character targeting a diversity of farmers, the inclusion of the latest science and climate change scenarios, as well as sound funding. The approach is well suited for working with farmers to co-develop local solutions that are based on discovery learning and support farmers to innovate and experiment in collaboration with advisory services and scientists. Tailored, locally specific and experimental approaches are however key (RFS 2021). FFS have been transferred across East Africa, showcasing the success of the peer-learning approach (FAO 2021b).

Terracing terrains

What is the issue ...

Rwanda is often called the "land of a thousand hills" due to its relief with an altitude averaging 1700 masl. As a small land-locked country, Rwanda has volcanic mountains at the northern fringe and undulating hills in most of the central plateau, while the eastern part is relatively flat. This relief pattern gives Rwanda a mild and cool climate that is predominantly influenced by its altitude (REMA 2009). Because of limited access to climate information, degraded forest stocks, and exacerbating factors such as extreme weather events, the country's hills and mountains are highly vulnerable to hazards like landslides, floods, and droughts. Communities across the country have witnessed a series of climate-induced disasters causing devastating impacts, such as crop destruction due to floods and landslides.

Terraces built on a steep slope ©FONERWA

The Gicumbi district, located in Rwanda's Northern Province, has been found to be the country's most exposed area to climate hazards and second most sensitive region to climate-related impacts (REMA 2019). Gicumbi extends north from Kigali to the Uganda border with its communities spread over 867 square kilometres, most of which (91,3 per cent) live in rural areas. The Muvumba River is a trans-boundary river located in the Buberuka Highlands. Both, the natural cutellate rainforest and a significant portion of wetlands in the Muvumba have been degraded or converted to agricultural use. The poor quality of existing forest resources and the deforestation of upper catchments contributes to high rates of soil erosion leading to reduced soil fertility, falling agricultural yields and increased food insecurity (Rwanda, Ministry of Environment 2018).

Agriculture is the main occupation for 94.8 per cent of the district's population. The main crops are tea (Gicumbi hosts one of the largest tea plantations in Rwanda), coffee, wheat, sorghum and maize, and many households (66 per cent) own farm animals, mostly cattle. As perennial plants, tea and coffee play an important role in stabilizing Rwanda's hilly topography and reducing soil erosion that would otherwise occur as a result of pre-planting tillage for annuals. However, both crops are highly sensitive to rising temperatures and changing rainfall patterns, leading to accelerated reduction of agricultural productivity. Slopes under intensive farming are often in poor condition with insufficient incorporation of soil conservation and stabilization measures (Rwanda, Ministry of Environment 2018).

Poverty rates within Gicumbi are also very high compared to national levels, which limit the adaptive capacity of communities to transition to more climate resilience farming systems and take on other income-generating opportunities to supplement household and livelihood needs. This particularly affects female-headed households, as women have limited access to and control over resources compared to men because of cultural and social stigmas/barriers and traditional roles and responsibilities (Rwanda, Ministry of Environment 2018).

How can it be solved ...

The project Strengthening Climate Resilience of Rural Communities in Northern Rwanda, or simply Green Gicumbi Project, is a six-year effort launched in 2019. Building on Rwanda's Green Growth and Climate Resilience Strategy (GGCRS), the country's roadmap for becoming a climate resilient, low carbon economy by 2050 (REMA 2011), the Green Gicumbi Project comprises four interlinked components, of which one focusses on promoting climate resilient agriculture practices along with building adaptive capacity of poor households to future climate risks and impacts. The adaptation scheme is funded and supported by the Green Climate Fund, and the Rwandan National Fund for Environment (FONERWA) is implementing the activities, focusing on watershed protection and climate smart agriculture (CSA).

To promote CSA practices, terracing has been introduced along the cultivated steep slopes. Terraces are step-shaped cuts into the mountainous landscape that are constructed to control flooding, reduce soil erosion and improve productivity. For example, prior to building the terraces, the manure that farmers applied to their plots was washed away by rain. Seeds are planted on the horizontal part of the terraces, where

the plants can grow in more nutritious soil (FONERWA n.d. a).

Research has shown the effectiveness of terracing while also demonstrating that terraces perform differently depending on the slopes (Rutebuka et al. 2021). For instance, progressive terraces built with contour bunds are suitable for more gentle slopes, while bench or radical terraces are preferrable for steeper slopes (Rwanda Water Resource Board n.d.). In Gicumbi, erosion control measures are planned by establishing 850 hectares of progressive terraces and biological control measures, and 400 hectares of radical terraces depending on the slopes´ gradient. Where slopes are less than 55°, terracing and agroforestry as well as the use of cover crops, which are fast growing and quickly cover the soil surface, have been chosen. With slopes greater than 55°, the focus is to phase out tillage systems and restore permanent vegetative cover and green manures, which will improve the nutrient levels in the soil and enhance growth of the main crop. The construction of radical and progressive terraces was accompanied by the re-planting of steep slopes with perennial grasses and agroforestry trees for greater soil stability (Rwanda, Ministry of Environment 2018; Rwanda, Ministry of Environment 2020).

Upon recommendations from District of Gicumbi technical experts, construction of radical terracing has been fast-tracked to two years in response to predicted unusual onset of rains in the short season and related risks of further erosion and landslides. Even though radical terraces are more labour intensive, this system already boosted the farmers' productivity as the terraces effectively help intercept rainwater run-off (Rwanda, Ministry of Environment 2020).

> *"Gicumbi used to experience strong erosion that caused severe damages to plantations. After the construction of terraces through the Green Gicumbi Project, the people no longer suffer from erosion, and they can do their agriculture with no hinderance.*
>
> – Marshall Banamwana, Acting Director, General Environment and Climate Change, Ministry of Environment

Who is benefitting ...

The Green Gicumbi Project targets 252 villages in the district with just under 250,000 residents (FONERWA n.d. b). Since the inception in October 2019, the solution has accomplished several outputs, including establishing 600 hectares of radical terraces and 600 hectares of progressive terraces (FONERWA n.d. c.). By 2020, 200,000 seedlings for agroforestry of both indigenous (Markhamia lutea and Mitragyna rubrospulocae) and non-indigenous trees (Grevillea robusta, Alnus accuminata and Acacia angussma) and 68,000 seedlings of fruit trees have been supported, leading to the establishment of 30 hectares of seed stands in the project area (Rwanda, Ministry of Environment 2021).

... and how could it work elsewhere?

As one of the oldest agricultural techniques for conserving water and soil, terracing is common in hilly and mountainous regions that are subjected to substantial population pressure and soil erosion processes. Terraced fields were constructed in Southeast Asia as early as 5,000 years ago and have since spread globally with well-known examples in the Hindu Kush Himalayas and the Andes (Deng et al. 2021).

Terracing offers numerous benefits and has particularly regained attention in regions where agriculture as main income source is under increased pressure to meet food needs of a growing population and variabilities caused by climate change (White 2016). As an integrative CSA approach to increase productivity in a sustainable manner, it is often a simple and affordable solution for smallholder farmers with scarce resources. However, some initial financial aid may be needed for planning, construction, and maintenance (Saiz et al. 2016).

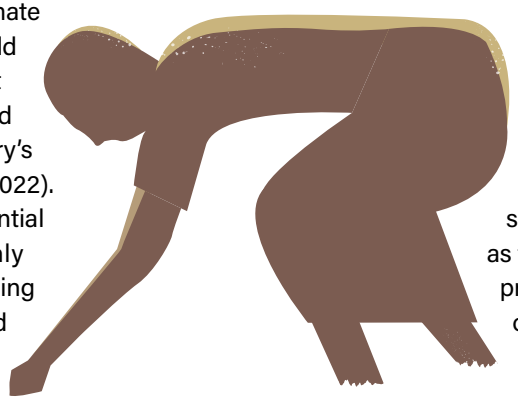
Careful analysis is needed for effectively establishing long-term benefits. Terracing alters the soil properties, therefore, in addition to assessing the gradient of the respective slope, studies regarding soil water and fertility management should be conducted (Fashaho et al. 2020). Further, climatic information (rainfall variability etc.), soil type (pH, nutrient levels and texture), plant species and competitive ability under a changing climate, and topography (slope stability and angle) are recommended to assess. It is also key to collaboratively discuss and plan terracing with the communities to consider local priorities and needs in an integrated approach for managing current and future climate hazards together with sustainable development (Rwanda, Ministry of Environment 2018).

Planting shade for coffee

What is the issue ...

The hilly areas of Burundi experience heavy soil loss due to erosion caused by land degradation, extreme rainfall, and loss of vegetation cover. The World Bank estimated the cost of erosion at USD 120 million per year, equivalent to 3.9 per cent of the country's gross domestic product. This has been a conservative estimate and the actual costs are probably higher (World Bank 2017). A high annual population growth of 3.3 per cent leads to additional population pressure in the already densely populated country. Unsustainable agricultural and land-use practices are a major factor contributing to erosion (World Bank 2017; Nibasumba et al. 2021). The average temperature in Burundi is expected to rise between 1.89 and 2.02°C by 2050. Coupled with a predicted precipitation increase of around 12-15 per cent until 2030-2050 and distortions to the existing precipitation regime, climate change further exacerbates the risk of losing the country's soil through erosion (Republique du Burundi 2021).

Coffee, tea, cotton, and sugar represent the main agricultural cash crops of Burundi. Rain-fed smallholder farming often takes place on the steep hillsides, and farmers have been constrained by severe shortage of arable land, low productivity, recurrent climate shocks, and poor agricultural practices (World Bank 2020b). The coffee bean is at the heart of Burundian agricultural export products and amounts to almost 70 per cent of the country's total export revenue (Trading Economics 2022). Gains vary from year to year due to substantial fluctuations in biennial production, mainly caused by increasing soil degradation, ageing plantations, pests, and diseases, exacerbated by climate change. Most of the coffee farmers reside at higher elevations of 1,500 to 2,000 metres, where historically promoted unshaded monocrop coffee growing practices on steep slopes and the removal of forest cover on hillsides have further contributed to degradation and agricultural encroachment into protected areas (World Bank Group 2019). Overall, there has been a decline in coffee production with significant ramifications for many people's livelihoods (Nibasumba et al. 2021) as all stages in coffee production including washing, drying, grading, storage, and other processing steps are a significant and much needed source of employment (World Bank 2013).



How can it be solved ...

For assisting Burundi to improve coffee cultivation which is critical to the economy for job creation, food security, poverty reduction, and natural resource management, the Sustainable Coffee Landscape Project (PADZOC) has been set up to target four main areas: (1) degraded coffee landscapes due to sun-grown coffee monocropping; (2) degraded protected areas due to encroachment of agricultural land and firewood collection; (3) polluted downstream water due to the environmentally unsound practices of coffee washing stations; and (4) low-quality coffee production and limited marketing (World Bank Group 2019).

The Bubanza, Bururi and Muyinga provinces were selected for implementation as they are all coffee-producing provinces that either contain or border protected areas.

To combat the erosion issues in hillside plantations, coffee farmers in these provinces received training to apply shade-grown techniques, and for sustainable land and water management. Shade-grown systems are polyculture techniques that involve intercropping coffee crops with other crops, for example bananas, beans or maize. These other crops provide shade for the coffee plants and protect them from the sun, reduce the exposure to heavy rainfall and strong winds. Intercropping is a sustainable coffee production technique that can improve soil aeriation and fertility, as well as offering additional food and cash crops, promoting local food security (Jassogne et al. 2013). The diversity of plants makes the agricultural system more resilient against climate shocks such as heat, drought, or heavy rain events. This in turn reduces the risk of erosion because of a more stable vegetation cover preventing the loss of soil.

Polyculture farming provides multiple benefits to farmers to improve coffee cultivation, including for other crops. Results from data collected to evaluate coffee growing conditions under different shading systems and with different cash crops in the selected provinces showed that Grevillea (shade-tree) and Banana (cash crop) are the most popular species associated with coffee. Their popularity relates to the fact that these species are the most profitable, multi-purpose and adapt well throughout the coffee landscape. Interviews with coffee growers have further confirmed that shade-grown coffee plants benefit from the microclimate created by shade trees as well as mulching and fertilization from falling leaves. Consequently, shade-grown coffee plants have an average but steady yearly yield. Shade-grown coffee plants are strong, lush and produce good quality cherries. Moreover, products such

Intercropping different plant species in Burundi ©Dave Proffer/ Wikimedia Commons

as timber, firewood and stakes from these trees are important sources of income during the lean season (World Bank Group 2019).

To transition to more sustainable coffee cultivation practices, the farmers received technical advice and support from the Ministry of Agriculture and Livestock, which has worked closely with community leaders in the local governments. To ensure that members of the rural communities fully embrace sustainable practices for coffee growing, a manual and booklet for profitable shade-grown coffee farming were translated into French and the local language Kirundi. This has made it easier for the communities to engage in sustainable coffee farming and contribute to the restoration of their mountain landscapes (World Bank Group 2019).

Who is benefitting ...

Between 2013 and 2018, over 18,700 people in the Bubanza, Bururi and Muyinga provinces benefited from PADZOC`s solutions and over 4,400 hectares were restored through sustainable land management. Shade-grown coffee production increased by 26 per cent, and of the 9,600 households that adopted the practice, half were headed by women. The project also targeted the indigenous Batwa community, a group which has historically faced exclusion. Through PADZOC, several Batwa households got the opportunity to save up money and purchase own land. Over 2 million coffee trees were planted, and each shaded tree increased on average its production by 101 grams compared to non-shaded trees (World Bank Group 2019).

PADZOC was undertaken in two phases over a period of almost six years (2013-2018). However, the government of Burundi, with support from the World Bank, decided to scale up the project by providing further funding through the Burundi Landscape Restoration and Resilience Project (2018-2023). The USD 30 million extension to the Landscape Restoration and Resilience Project will be invested to scale up the restoration of other degraded landscapes and support the sustainable management of the Bururi Forest Nature Reserve and the Kibira and Ruvubu National Parks. More than 90,000 hectares are expected to be restored benefiting 80,000 households.This continuation is implemented by the Burundian Ministry of Agriculture and Livestock and financed by the GEF.

... and how could it work elsewhere?

The solution of polyculture farming and intercropping presents a CSA approach well suited for degraded landscapes in mountainous or hilly terrains that are already heavily impacted by erosion processes as an accelerated effect of climate change. Increasing agricultural diversity within crop farming not only boosts productivity of the cash crop, thus secures farmer´s income, but also enhances soil stability for cultivation on steep slopes and avoids encroaching in protected areas. Additional benefits include landscape restoration, local ownership, and elevating the livelihoods of previously marginalized groups.

> ***The project has improved our coffee farming, most of the farmers are happy since they benefit from selling coffee but also get enough food from the crops grown alongside coffee. The community now looks greener than in the past years.***
>
> – Pius Ndarushimana, a coffee farmer in Buhinyuza, Muyinga province

Greenhouses for green fields

What is the issue ...

The Taita Hills consist of the Dawida and Mbololo massifs and are part of the Eastern Arc Mountains in the south-eastern corner of Kenya. This area has seen a significant fragmentation and reduction of mountain forest cover, much of which is due to the expansion of agricultural land (Pellikka et al. 2013). Agriculture is the main source of livelihood, contributing to approximately 95 per cent of household incomes and over 80 per cent of employment (Kenya, Ministry of Agriculture, Livestock and Fisheries [MoALF] 2016b). The average farm size is about 0.4 hectares in the highlands, translating into low yields per household (County Government of Taita Taveta 2018).

Rainfall patterns in Taita Hills are bimodal, with long rains occurring between March and May, and short rains between October and December (Ogallo et al. 2019). With increasing climate variability, the county has faced seasonal changes whereby the rainy seasons have reduced and the onset of the rains delayed, causing prolonged drought periods. The Taita-Taveta County Integrated Development Plan (2018) indicates drought occasioned by climate change as a key challenge that is placing a heavy strain on the county's economy with reduced crop yields leading to food insecurity, reduced nutrition and threatening local livelihoods. Longer dry spells make it increasingly challenging for the smallholder farmers that heavily depend on rain-fed agriculture to sustain their livelihoods on scarce arable land. Temperature fluctuations additionally lead to increased incidences and emergence of new pests and diseases (MoALF 2016b), damaging agriculture productivity and heightening the vulnerability of local communities.

> *"The Members of the group have been able to boost vegetable production through the use the use of drip irrigation and greenhouse technology. Their incomes have increased because they have vegetables to sell despite challenging climatic conditions.*
>
> – Gilbay Obunga, Project Officer, Nature Kenya

How can it be solved ...

Under the People and Nature Programme, Nature Kenya has been supporting communities in the Taita Hills to counter the effects of climate change and build resilient livelihoods through participatory community engagement. One prominent approach is forming farming self-help groups for jointly planning and implementing adaptation responses to changing climatic conditions and finding solutions to make them less reliant on sufficient rain for irrigating their crops.

In 2015, Nature Kenya supported the Mwavunyu Chakiloli self-help group, which consists of some 15 farmers involved in vegetable cultivation, to construct greenhouses and drip irrigation. Greenhouses were chosen because they can extend growing seasons and create optimal growing conditions by regulating humidity and temperature. This makes it possible to continue farming amidst periods of rain scarcity, hence increasing cultivation resilience during drought events. In addition, the spread of crop pests and diseases can be better controlled compared to open fields. With the purchase of micro-climate control systems, optimal growing conditions are fostered, and yield and economic outputs improved (Sanzua, Saha and Mwafaida 2019).

Greenhouses for small-scale farmers can be built relatively easily using metallic, or alternatively hard wood, stands as frame, and plastic sheeting or glass as cover. In the People and Nature Programme, polythene sheeting was chosen, which is a sturdy plastic that filters UV rays with benefits for pest control. The size of each greenhouse has been determined based on the availability of resources including land, finances, and labour.

After setting up the garden and planting inside the greenhouse, an irrigation system is built using plastic pipes with 'drippers' that slowly emit drops of water. This drip system is connected to water tanks supplying the pipes, and the farmers monitor the plants to ensure they receive the right amount of water. Along slopes, the natural water flow due to gravity may make pumps redundant, thus minimal or no energy supply is needed. The system is easy to manage and maintain once installed as it only requires the supervision of the water supply.

Who is benefitting ...

According to Nature Kenya, the production of vegetables with greenhouses and drip irrigation increased fivefold compared to previous cultivation practices. The higher yields have created a reliable source of income and food for households and have led to an improvement in food security and livelihoods for the families involved. The vegetables grow faster and are less prone to climate stressors including droughts and pests. Among the 12 self-help groups that were formed under the People and Nature Programme in the Taita Hills, the Mwavunyu Chakiloli group has been one of the more successful ones. The members have offered training on greenhouse farming using drip irrigation to other groups.

Gender mainstreaming has also played an important role in the solution. This includes a gender participation rule where 60 per cent of beneficiaries in the activities must be female.

… and how could it work elsewhere?

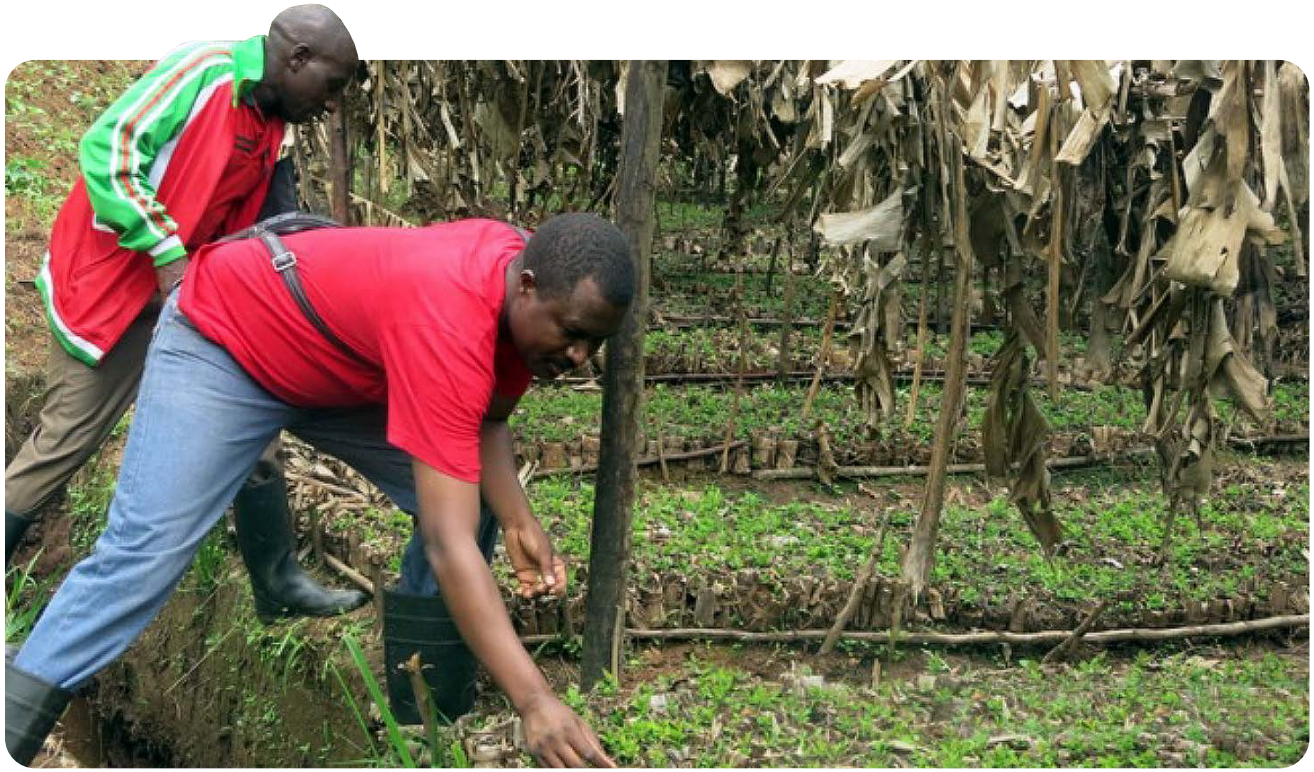
Farmers in other mountain communities facing drought and unstable growing conditions can adopt greenhouse technologies using drip irrigation to secure a continuous production of vegetables. A key requirement is to have a reliable source of water such as a nearby reservoir for constant water supply. Building materials and the technologies used are relatively affordable and do not require much training to maintain. Another success factor is the formation of bottom-up community groups that drive the process and share their experiences with others.

Members of the Wuchichi Women Group from the Iyale area investigate the operations in a Greenhouse by the Mwavunyu Chakiloli group during a peer-to-peer learning session ©Nature Kenya

Nursing trees for tilted farming

What is the issue ...

Many farmers support their livelihoods on the exposed steep hills within the Lake Tanganyika Basin, which is shared between the four countries Tanzania, the Democratic Republic of the Congo (DRC), Burundi, and Zambia. Lake Tanganyika lies at an elevation of about 772 masl in the western part of the Great Rift Valley and is confined by a landscape of surrounding steep slopes. The lake ecosystem is facing a multitude of challenges mainly arising from rapid population growth and intensified human activities, which have induced changes in land use patterns and deforestation and resulted in an increase in soil erosion and sediment loads transported into the lake. With more heavy precipitation events on the one hand, and population growth combined with unsustainable agricultural practices on the other, the vulnerability to erosion, landslides, and food insecurity on the hillsides has increased. Heavy rains cascade down the slopes, creating erosion that drains agricultural soil of nutrients and therefore reduces its fertility. Furthermore, landslides in the region pose a severe threat to human life and infrastructure (Magero 2017).



Farmers working on their field ©BirdLife International

This soil run-off also has a negative impact on nearby rivers by adding sediments that increase turbidity. The turbidity in turn reduces the quality of drinking water, lowers rivers' oxygen levels, negatively affecting fish populations, and decreases hydropower output in the region (Akayezu, Bizimungu and Bucankura 2019).

Communities in the Lake Tanganyika Basin have further suffered from heavy winds that are exacerbated by climate change. Strong winds can severely damage people's homes, roads, and fields.

How can it be solved ...

To comprehensively approach these challenges, a Climate Resilient Altitudinal Gradients (CRAG) approach has been fostered in Burundi and neighbouring Rwanda. CRAGs are landscape units where the minimum elevation range is 1,000 metres. These landscape units are vertically interlinked in their climate resilient biodiversity and ecosystem service values. Therefore, intervention along the altitudinal range has upward- and downward impacts on the units' climate resilience (Magero 2017). The CRAGs approach combines a variety of conservation efforts, such as integrated water management, Ecosystem-based Adaptation, combating soil erosion and water pollution as well as afforestation. In this regard, this holistic approach is designed to provide benefits across a landscape gradient both for the local population and biodiversity values (Poelking 2019).

The CRAG project in Burundi was initiated by BirdLife International, implemented by the Burundian Association for the Protection of Nature (Association Burundaise pour la Protection de la Nature – ABN), and funded by the MacArthur Foundation and The Nature Conservancy.

Community working together to plant seedlings ©BirdLife International

Over the past years, BirdLife International has worked with local community cooperatives in Burundi to collect samples from various locations throughout the watershed, starting high in the mountains and ending down by the lakes, to identify the most vulnerable erosion hotspots (Poelking 2019).

Based on identified erosion hotspots, community representatives and experts developed site specific interventions under the broader CRAG approach. They co-designed an intervention plan, that details various conservation and restoration efforts, proposed a monitoring protocol to track the effectiveness of the interventions, and elaborated an indicative costing of the intervention and its monitoring at that site over a three-year period (Manten, Ntungane and Akayezu 2016).

In the effort to adopt agroforestry practices, trees have been planted by more than 200 farmers alongside their crops in the Lake Tanganyika Basin in Burundi (Akayezu, Bizimungu and Bucankura 2019). A nursery started with 38,000 Prinus Africana plants and 158,000 Grevillea plants, a species that is known to coexist well with other crops (Miriti n.d.). Mixing in trees diversifies the agricultural output, improves degraded vegetation, and protects exposed soil. Trees act as natural barriers to rainwater washing over the slopes, binding the soil and thus limiting the drainage of its nutrients. Through the development of root systems, mountain trees further cohere the soil and make it more permeable to store and filter water. This reduces the risk of flash floods and landslides. Lastly, the trees act as natural barriers against storms, substantially reducing the speed and magnitude of winds (Makino and Rudolf-Miklau 2021).

Further, co-developed interventions focused on additional CSA techniques, such as terracing, promoting zero-till agriculture, and mulching to increase vegetation cover and soil health, thus reducing excessive rainwater run-off and avoiding river sedimentation. Moreover, a selection of climate-smart crop species has been introduced that provide a better coping capacity with increased rainfall and warmer temperatures (BirdLife International n.d.).

Who is benefitting ...

At least 267 community members have been engaged in setting up tree nursery beds with 834,000 seedlings in the Ruhwa and Muhira catchments of the Lake Tanganyika Basin. ABN also provided 5,000 fruit trees to communities of Murwi and Mugina in the Cibitoke province.

In a participatory approach and to ensure community buy-in, ABN hosted local workshops involving 53 community members to map the environmental challenges they face and discuss potential interventions (Akayezu, Bizimungu and Bucankura 2019). The joint development of the CRAG intervention plan has been instrumental for community efforts introducing new techniques for conservation and sustaining their livelihoods.

In addition to Burundi, the CRAG solution has proven successful in the neighbouring countries of Rwanda and the DRC. In the three countries combined, this integrated landscape solution provides ecosystem services to over 2 million people (BirdLife International n.d.).

... and how could it work elsewhere?

Although CRAG has location-specific elements, it contains aspects such as agroforestry that can inspire adaptation solutions in other regions with steep topography. Ecosystem-based Adaptation has the potential to produce multiple benefits for the environment, biodiversity, and local communities. An important success factor is a community approach that includes beneficiaries from the beginning to ensure that the project is tailored to their needs and fits the local context. In addition, it is important to identify and foster the co-benefits of CRAG, such as strengthening livelihoods through additional agricultural diversity and stronger protective functions of mountain forests against climate hazards.

References

Abebe, M. A. (2014). Climate change, gender inequality and migration in East Africa. *Washington Journal of Environmental Law and Policy*. 4, 104-140. https://digitalcommons.law.uw.edu/wjelp/vol4/iss1/6/.

Adler, C., Wester, P., Bhatt, I., Huggel, C., Insarov, G.E., Morecroft, M.D., Muccione, V. and Prakash, V. (2022). Cross-Chapter Paper 5: Mountains. *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Pörtner, H.-O., Roberts, D.C., Masson-Delmotte, V., Zhai, P., Tigner, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama, B., Weyer, N.M. (eds.).] Cambridge University Press. In Press. https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_CrossChapterPaper5.pdf.

Afifi, T., Liwenga, E. and Kwezi, L., (2014). Rainfall-induced crop failure, food insecurity and out-migration in Same-Kilimanjaro, Tanzania. *Climate and Development*, *6*(1), 53-60. https://doi.org/10.1080/17565529.2013.826128.

African Forest Landscape Restoration Initiative (2021). Commitment Tracker. https://afr100.org. Accessed 3 November 2021.

Agroforestry Network, Agroforestry Sverige, Focali, NIRAS, SIANI, SLU Global, SwedBio & Vi-skogen (2018). *Achieving the Global Goals through agroforestry.* http://agroforestrynetwork.org.hemsida.eu/wp-content/uploads/2018/09/Achieving-the-Global-Goals-through-agroforestry.pdf.

Akayezu, P., Bizimungu, J. and Bucankura, J. (2019). Transforming livelihoods through nature-based solutions in Burundi, 5 November. Cambridge: BirdLife International (n.d.). https://web.archive.org/web/20210525132146/https://www.birdlife.org/africa/news/transforming-livelihoods-through-nature-based-solutions-burundi. Accessed 13 December 2021.

BirdLife International (n.d.). *Building the Climate Change Resilience in the Lake Kivu and Rusizi River Catchments: CRAGs II project*. Cambridge.

Chará, J., Reyes, E., Peri, P., Otte, J., Arce, E. and Schneider, F. (2019). *Silvopastoral Systems and their Contribution to Improved Resource Use and Sustainable Development Goals (SDG): Evidence from Latin America*. Cali: Food and Agriculture Organization of the United Nations. https://www.fao.org/3/ca2792en/CA2792EN.pdf.

Chocholata, L. (2020). *Farmer field schools, gender equality, social inclusion and community empowerment – Experiences from Uganda – Karamoja sub-region, case study*. Rome: Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/cb0709en.

Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (eds.) (2016). *Nature-based Solutions to Address Global Societal Challenges*. Gland: International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2016.13.en.

County Government of Nyandarua (2018). *The socio-economic transformative agenda for Nyandarua County. Nyandarua County Integrated Development plan (CIDP2) 2018-2022.* Ol Kalou. http://www.nyandarua.go.ke/wp-content/uploads/2020/09/NYANDARUA_COUNTY_CIDP2.pdf.

County Government of Taita Taveta (2018). *Taita Taveta County Integrated Development Plan 2018-2022. CIDP;2018-2022*. Wundanyi. http://repository.kippra.or.ke/handle/123456789/2360.

Davies, R. (2021). *Uganda – Hundreds Displaced After More Floods in Kasese.* https://floodlist.com/africa/uganda-floods-kasese-september-2021. Accessed 31 January 2022.

Deng, C., Zhang, G., Liu, Y., Nie, X., Li, Z., Liu, J. *et al.* (2021). Advantages and disadvantages of terracing: A comprehensive review. *International Soil and Water Conservation Research*, 9(3), 344-359. https://doi.org/10.1016/j.iswcr.2021.03.002.

De Stefano, A. and Jacobson, M.G. (2018). Soil carbon sequestration in agroforestry systems: A meta-analysis. *Agroforestry Systems* 92(2), 285-299. https://doi.org/10.1007/s10457-017-0147-9.

Dell'Angelo, J., McCord, P.F., Baldwin, E., Cox, M.E., Gower, D., Caylor, K. and Evans, T.P. (2014). Multilevel governance of irrigation systems and adaptation to climate change in Kenya. *The global water system in the Anthropocene* [Bhaduri, A., Bogardi, J., Leentvaar, J., Marx, S. (eds.)]. Springer: Cham. Chapter 21. 323-342.

East African Community [EAC] (2020). *Agriculture and Food Security Department*. Brief 1 September 2020. Arusha.

East African Community, United Nations Environment Programme and GRID-Arendal (2016). *Sustainable Mountain Development in East Africa in a Changing Climate*. Arusha, Nairobi and Arendal. https://www.grida.no/resources/8422.

Eastern Arc Mountains Conservation Endowment Fund [EAMCEF] (n.d.). *If it were not for the bees...* http://www.easternarc.or.tz/if-it-were-not-for-the-bees/. Accessed 10 December 2021.

Eastern Arc Mountains Conservation Endowment Fund [EAMCEF] (2013). Baseline Survey Report for 8 Nature Reserves and 1 National Park in the Eastern Arc Mountains of Tanzania*. Environmental and Social Management Framework for the Resilient Natural Resources Management for Tourism and Growth Project* (2017). Dar es Salaam: Ministry of Natural Resources and Tourism. https://ewsdata.rightsindevelopment.org/files/documents/23/WB-P150523_kTCEpJM.pdf.

Elephants and Bees Project (n.d.). *Meet some of our participating farmers.* https://elephantsandbees.com/our-farmers/. Accessed 16 December 2021.

Equator Initiative (n.d.). Cold Trout Fish Farming. https://www.equatorinitiative.org/2017/08/03/cold-trout-fish-farming/. Accessed 10 December 2021.

Falchetta, G., Hafner, M. and Tagliapietra, S. (2020). Pathways to 100% electrification in East Africa by 2030. *The Energy Journal,* 41(3). https://doi.org/10.5547/01956574.41.3.gfal.

Fashaho, A., Ndegwa, G.M., Lelei, J.J., Musandu, A.O. and Mwonga, S.M. (2020). Effect of land terracing on soil physical properties across slope positions and profile depths in medium and high altitude regions of Rwanda. *South African Journal of Plant and Soil* 37(2), 91-100. https://doi.org/10.1080/02571862.2019.1665722.

Fatiah, N. (2018). Japan supports Atari rice irrigation scheme with UGX93bn. Nile Post (n.d.). https://nilepost.co.ug/2018/11/07/japan-supports-atari-rice-irrigation-scheme-with-ugx93bn/. Accessed 10 December 2021.

Fennell, D. and Weaver, D. (2005). The ecotourism concept and tourism-conservation symbiosis. *Journal of Sustainable Tourism,* 13(4), 373-390. https://doi.org/10.1080/09669580508668563.

Food and Agriculture Organization of the United Nations (2015). *The State of Food and Agriculture Social protection and agriculture: breaking the cycle of rural poverty*. Rome. https://www.fao.org/3/i4910e/i4910e.pdf.

Food and Agriculture Organization of the United Nations (2021a). *Climate-smart agriculture case studies 2021 – Projects from around the world.* Rome. https://doi.org/10.4060/cb5359en.

Food and Agriculture Organization of the United Nations (2021b). *Institutionalizing Farmer Field School methodologies in the Universities*

Curricula in Eastern Africa. [online video]. https://www.youtube.com/watch?v=u3Sw0TrNiww. Accessed 27 January 2022.

Food and Agriculture Organization of the United Nations (2022). *Sustainable Forest Management (SFM) Toolbox.* https://www.fao.org/sustainable-forest-management/toolbox/modules/agroforestry/basic-knowledge/en/. Accessed 15 March 2022.

Food and Agriculture Association, International Union for Conservation of Nature´s Commission on Ecosystem Management and Society for Ecological Restoration (2021). *Principles for ecosystem restoration to guide the United Nations Decade 2021–2030*. Rome. https://www.fao.org/3/cb6591en/cb6591en.pdf.

Gaworek-Michalczenia, M.F., Sallu, S.M. and Di Gregorio, M. (2019). *Mediating Vulnerability and Livelihood Resilience in the East Usambara Mountains: Challenges, Opportunities and Lessons Learned.* Sustainability Research Institute Briefing Note Series No. 25. Leeds: Sustainability Research Institute. https://doi.org/10.13140/RG.2.2.13137.07527.

Gordon, E. (2018). *The Politics of Renewable Energy in East Africa*. Oxford: The Oxford Institute for Energy Studies. https://doi.org/10.26889/9781784671181.

Hairiah, K., Widianto, W., Suprayogo, D. and Van Noordwijk, M. (2020). Tree roots anchoring and binding soil: Reducing landslide risk in Indonesian agroforestry. *Land* 9(8), 256. https://doi.org/10.3390/land9080256.

Hock, R., Rasul, G., Adler, C., Cáceres, B., Gruber, S., Hirabayashi, Y. *et al.* (2019). High Mountain Areas Supplementary Material. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H.-O., Roberts, D.C., Masson-Delmotte, V., Zhai, P., Tigner, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama, B., Weyer, N.M. (eds.)]. In press. Chapter 2. 131-202.

Ikeno, J. (2018). Intra-and Inter-Sectorial Competition for Water Resources around Mwanga Town in Kilimanjaro Region, Tanzania. *African study monographs. Supplementary issue, 55*, 101-118. https://doi.org/10.14989/230166.

Intergovernmental Panel on Climate Change (2021). *Regional fact sheet – Mountains*. https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Mountains.pdf.

International Union for Conservation of Nature (n.d. a). *Landscape and integrated water resources management and restoration in Sebeya and other catchments*. https://www.iucn.org/regions/eastern-and-southern-africa/our-work/forest-landscape-livelihoods/landscape-and-integrated-water-resources-management-and-restoration-sebeya-and-other-catchments. Accessed 13 December 2021.

International Union for Conservation of Nature (n.d. b). *Supporting the Rwanda Water Resources Board to strengthen the Water Management Information System (MIS).* https://www.iucn.org/regions/eastern-and-southern-africa/our-work/forest-landscape-livelihoods/landscape-and-integrated-water-resources-management-and-restoration-sebeya-and-other-catchments/monthly-update-december-2020-2. Accessed 13 December 2021.

International Union for Conservation of Nature (n.d. c). *Engaging communities in conservation of the Sebeya catchment.* https://www.iucn.org/regions/eastern-and-southern-africa/our-work/forest-landscape-livelihoods/landscape-and-integrated-water-resources-management-and-restoration-sebeya-and-other-catchments/ewmr-project-updates-and-0. Accessed 13 December 2021.

International Union for Conservation of Nature (n.d. d). *IUCN and RWB conduct consultation meetings for Mukungwa and Akagera catchment management plans*. https://www.iucn.org/regions/eastern-and-southern-africa/our-work/forest-landscape-livelihoods/landscape-and-integrated-water-resources-management-and-restoration-sebeya-and-other-catchments/ewmr-project-updates-and-1. Accessed 13 December 2021.

International Union for Conservation of Nature (2017). *Ecosystem-based Adaptation*. Issues Brief. Gland. https://www.iucn.org/sites/dev/files/import/downloads/ecosystem-based_adaptation_issues_brief_final.pdf.

Intergovernmental Panel on Climate Change (2021). Summary for Policymakers. *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf.

Intergovernmental Panel on Climate Change (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Pörtner, H.-O., Roberts, D.C., Tignor, D.C., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., Rama, B. (eds.)]. Cambridge University Press. In Press. https://www.ipcc.ch/report/ar6/wg2/.

Japan International Cooperation Agency (2017). *The Project on Irrigation Scheme Development in Central and Eastern Uganda, Final Report*. Volume-III Atari Irrigation Scheme Development Project. Ministry of Agriculture, Animal Industry and Fisheries and Ministry of Water and Environment. Tokyo. https://www.jica.go.jp/english/our_work/social_environmental/id/africa/uganda/c8h0vm0000b1pkfv-att/c8h0vm0000d1y3l6.pdf.

Jassogne, L., Nibasumba, A., Wairegi, L., Baret, P.V., Deraeck, J., Mukasa, D. *et al.* (2013). Coffee/banana intercropping as an opportunity for smallholder coffee farmers in Uganda, Rwanda and Burundi. *Banana Systems in the Humid Highlands of Sub-Saharan Africa: Enhancing Resilience and Productivity*. [ebook] [Blomme, G., Asten. P. van, and Vanlauwe. B. (eds.)]. CAB International. Chapter 18. 144-149. http://dx.doi.org/10.1079/9781780642314.0144.

Kenya Institute for Public Policy Research and Analysis (2020). *Kenya Economic Report 2020. Creating an Enabling Environment for Inclusive Growth in Kenya.* Nairobi. https://kippra.or.ke/wp-content/uploads/2021/02/Kenya-Economic-Report-2020.pdf.

Kenya Ministry of Agriculture, Livestock and Fisheries [MoALF] (2016a). *Climate Risk Profile for Nyandarua. Kenya County Climate Risk Profile Series.* Nairobi. https://ccafs.cgiar.org/resources/publications/climate-risk-profile-nyandarua-county-kenya-county-climate-risk-profile.

Kenya Ministry of Agriculture, Livestock and Fisheries [MoALF] (2016b). *Climate Risk Profile for Taita Taveta. Kenya County Climate Risk Profile Series.* Nairobi. https://cgspace.cgiar.org/bitstream/handle/10568/80445/Taita%20Taveta_Climate%20Risk%20Profile.pdf.

King, L.E. (2019). *Beehive Fence Construction Manual. A step by step guide to building a protective beehive fence to deter crop-raiding elephants from farm land*. Nairobi: The Elephants and Bees Project. https://elephantsandbees.com/wp-content/uploads/2019/07/LKING-2019-Beehive-Fence-Construction-Manual-4th-edition.pdf.

King, L.E. (2010). *The interaction between the African elephant (Loxodonta cutella cutella) and the African honey bee (Apis mellifera cutellate) and its potential application as an elephant deterrent*. PhD thesis. Oxford: Oxford University Press.

Kisakye, V., Akurut, M. And Van der Bruggen, B. (2018). Effect of climate change on reliability of rainwater harvesting systems for

Kabarole District, Uganda. *Water*, 10(1), 71. https://doi.org/10.3390/w10010071.

Magero, C. (2017). Climate Resilient Altitudinal Gradients (CRAGs). Building Climate Change Resilience in the Kivu-Rusizi Watersheds. Great Lakes Conference [presentation]. Entebbe. https://www.riob.org/fr/file/288902/download?token=t4Rqf8q6.

Makino, Y. and Rudolf-Miklau, F. (2021). The Protective Functions of Forests in a Changing Climate – European Experience. *Forestry Working Paper* No. 26. Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/3/cb4464en/cb4464en.pdf.

Mamalakis, A., Randerson, J.T., Yu, J.Y., Pritchard, M.S., Magnusdottir, G., Smyth, P. *et al.* (2021). Zonally contrasting shifts of the tropical rain belt in response to climate change. *Nature Climate Change* 11(2), 143-151. https://doi.org/10.1038/s41558-020-00963-x.

Mansourian, S. and Berrahmouni, N. (2021). *Review of Forest and Landscape Restoration in Africa*. Accra: Food and Agriculture Organization of the United Nations and African Union Development Agency-New Partnership for Africa's Development. https://doi.org/10.4060/cb6111en.

Manten, M., Ntungane, J.P., Akayezu, P. (2016). *Efforts to enhance climate change resilience in the Lake Kivu and Rusizi River Basins*. Cambridge: BirdLife International. https://www.cepf.net/sites/default/files/65995-rwanda-climate-change-resilience-lake-kivu-rusizi-river-basins.pdf.

Mbow, C., Smith, P., Skole, D., Duguma, L. and Bustamante, M. (2014). Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Current Opinion in Environmental Sustainability,* 6, 8-14. https://doi.org/10.1016/j.cosust.2013.09.002.

McAlpine, C.A., Johnson, A., Salazar, A., Syktus, J., Wilson, K., Meijaard, E. *et al.* (2018). Forest loss and Borneo's climate. *Environmental Research Letters,* 13(4), 044009. https://doi.org/10.1088/1748-9326/aaa4ff.

Mdeke, J.O. and Kabyemela, M.A. (2015). *Managing water: Water-harvesting technology using micro dams: A case study of same district, Tanzania*. https://cgspace.cgiar.org/bitstream/handle/10568/66419/30_WaSA_Ch3.8.pdf?sequence=1&isAllowed=y.

Mira-Salama, D. (2017). *Project Information Document (Appraisal Stage) – Tanzania: Resilient Natural Resource Management for Tourism and Growth – P150523 (English).* Washington, D.C: World Bank. http://documents.worldbank.org/curated/en/763761501932643705/Project-Information-Document-Appraisal-Stage-Tanzania-Resilient-Natural-Resource-Management-for-Tourism-and-Growth-P150523.

Miriti E. (n.d.) CRAG: Fighting Climate Change in Burundi. *African Great Lakes Information Platform.* https://www.africangreatlakesinform.org/article/crag-fighting-climate-change-burundi. Accessed 15 March 2022.

Mul, M.L., Kemerink, J.S., Vyagusa, N.F., Mshana, M.G., van der Zaag, P. and Makurira, H. (2011). Water allocation practices among smallholder farmers in the South Pare Mountains, Tanzania: The issue of scale. *Agricultural Water Management* 98(11), 1752–1760. https://doi.org/10.1016/j.agwat.2010.02.014.

National Aeronautics and Space Association (2009*). Gishwati Forest, Rwanda*. https://earthobservatory.nasa.gov/images/38644/gishwati-forest-rwanda?src=ve. Accessed 15 March 2022.

National Fund for Environment (n.d. a). *Green Gicumbi Project launches the Forestry Planting Season 2020-2021*. http://www.fonerwa.org/greengicumbi/launch. Accessed 13 December 2021.

National Fund for Environment (n.d. b). *Project Background*. http://fonerwa.org/greengicumbi/project-background. Accessed 15 March 2022.

National Fund for Environment (n.d. c). *Green Gicumbi.* http://fonerwa.org/greengicumbi. Accessed 15 March 2022.

Ngoma, H., Wen, W., Ojara, M. and Ayugi, B. (2021). Assessing current and future spatiotemporal precipitation variability and trends over Uganda, East Africa based on CHIRPS and regional climate models datasets. *Meteorology and Atmospheric Physics,* 133, 823-843. https://doi.org/10.1007/s00703-021-00784-3.

Ngotho, A. (2021). *Nyandarua farmers to get bio-digesters for clean cooking gas*. The Star. https://www.the-star.co.ke/news/star-farmer/2021-09-27-nyandarua-farmers-to-get-bio-digesters-for-clean-cooking-gas/. Accessed 13 December 2021.

Nibasumba, A., Jassogne, L., Nduwayo, G., Ngayempore, E., Simbashizubwoba, C., VanAsten, P. *et al.* (2021). Status and management of coffee plantations in Burundi: Reasons to worry. *African Journal of Agricultural Research* 17(9), 1180-1191. http://dx.doi.org/10.5897/AJAR2021.15494.

Nicol, A.; Langan, S.; Victor, M.; Gonsalves, J. (Eds.) (2015). *Water-smart agriculture in East Africa*. Colombo: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE); Kampala: Global Water Initiative East Africa (GWI EA). https://doi.org/10.5337/2015.203.

NIRAS (n.d. a). *Water for Eastern Equatoria (W4EE)*. Allerød: NIRAS. https://www.niras.com/media/p5ml1zc3/water-for-ee-brochure_final-1-compressed.pdf.

NIRAS (n.d. b). *Clean drinking water for 330,000 people in South Sudan*. Allerød: NIRAS. https://www.niras.com/projects/clean-drinking-water-for-330-000-people-in-south-sudan/. Accessed 13 December 2021.

Nyamai, F. (2020). *Forget tilapia, trout is the money minter.* Nation. https://nation.africa/kenya/business/seeds-of-gold/forget-tilapia-trout-is-the-money-minter-1145506?view=htmlamp. Accessed 10 December 2021.

Ogallo, L., Omay, P., Kabaka, G., Lutta, I. (2019). *Report on Historical Climate Baseline Statistics for Taita Taveta, Kenya.* Vol 1. Nairobi: IGAD Climate Prediction and Application Centre.

Olsson, L., H. Barbosa, S. Bhadwal, A. Cowie, K. Delusca, D. Flores-Renteria, K. Hermans, E. Jobbagy, W. Kurz, D. Li, D.J. Sonwa, L. Stringer (2019). Land Degradation. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press. https://www.ipcc.ch/site/assets/uploads/sites/4/2019/11/07_Chapter-4.pdf.

Ongoma, V., Chen, H. and Gao, C. (2018). Projected changes in mean rainfall and temperature over East Africa based on CMIP5 models. *International Journal of Climatology*, 38(3), 1375-1392. https://doi.org/10.1002/joc.5252.

Pellikka, P.K., Clark, B.J., Gosa, A.G., Himberg, N., Hurskainen, P., Maeda, E., Mwang'ombe, J., Omoro, L.M. and Siljander, M. (2013). Agricultural expansion and its consequences in the Taita Hills, Kenya. *Kenya: A Natural Outlook: Geo-Environmental Resources and Hazards* [Paron, P., Olago, D. O., Omuto, C. T (eds.)]. Elsevier.. Chapter 16. 165-179. https://doi.org/10.1016/B978-0-444-59559-1.00013-X.

Pilato, G., Sallu, S.M. and Gaworek-Michalczenia, M. (2018). *Climate Compatible Development at Local Levels: Assessing the integration of climate and development strategies in Muheza District, Tanzania.* Sustainability Research Institute Briefing Note Series No. 12. Leeds: Sustainability Research Institute. http://www.see.leeds.ac.uk/fileadmin/Documents/research/sri/briefingnotes/SRIBNs-12.pdf.

Pilloni, M., & Hamed, T. A. (2021). Small-Size Biogas Technology Applications for Rural Areas in the Context of Developing

Countries. *Anaerobic Digestion in Built Environments* [Sikora, A. (ed.)]. IntechOpen. Chapter 4. 57-80. https://doi.org/10.5772/intechopen.96857.

Poelking, C (2019). *Climate Smart Conservation*. MacArthur Foundation (n.d.). https://www.macfound.org/press/perspectives/climate-smart-conservation. Accessed 15 March 2022.

Prinz, R., Heller, A., Ladner, M., Nicholson, L.I. and Kaser, G. (2018). Mapping the loss of Mt. Kenya's glaciers: An example of the challenges of satellite monitoring of very small glaciers. *Geosciences* 8(5), 174. https://doi.org/10.3390/geosciences8050174.

Republic of Burundi (2019). *Third National Communication on Climate Change (TNCCC)/ Executive Summary*. Bujumbura: Ministry of Environment, Agriculture and Livestock. https://unfccc.int/sites/default/files/resource/Burundi%20TNC%20executive%20summary.pdf.

Republique du Burundi (2021). *Contribution Determinee Au Niveau National 2020*. Bujumbura. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Burundi%20First/CDN%20%20%20Burundi%20ANNEXE%201.pdf.

Resilient Food Systems (2019). *FAO trains farmers in Burundi to combat soil erosion through agroforestry and contour planting*. https://www.resilientfoodsystems.co/news/fao-trains-farmers-in-burundi-to-combat-soil-erosion-through-agroforestry-and-contour-planting. Accessed 13 December 2021.

Resilient Food Systems (2020). *Resilient Food Systems: Programme Highlights 2020*. Nairobi: International Centre for Research in Agroforestry. https://www.resilientfoodsystems.co/assets/resources/pdf/rfs_annual-report_spread_final_interactive.pdf.

Resilient Food Systems (2021). *Resilient Food Systems Annual Workshop Report 2021: Summary of virtual leaning and exchange events*. Nairobi: International Centre for Research in Agroforestry. https://knowledgecentre.resilientfoodsystems.co/assets/resources/pdf/rfs_annual-workshop-report-2021_23_02_22_spread.pdf.

Romeo, R., Grita, F., Parisi, F. and Russo, L. (2020). *Vulnerability Of Mountain Peoples To Food Insecurity: Updated Data And Analysis Of Drivers*. Rome: Food and Agriculture Organization of the United Nations and United Nations Convention to Combat Desertification. https://doi.org/10.4060/cb2409en.

Romeo R., Russo, L., Parisi, F., Norarianni M., Manuelli S. and Carvao S., UNWTO (2021). *Mountain tourism – Towards a more sustainable path*. Rome: Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/cb7884en

Rutebuka, J., Uwimanzi, A.M., Nkundwakazi, O., Kagabo, D.M., Mbonigaba, J.J.M., Vermeir, P. *et al.* (2021). Effectiveness of terracing techniques for controlling soil erosion by water in Rwanda. *Journal of Environmental Management,* 277, 111369. https://doi.org/10.1016/j.jenvman.2020.111369.

Rwanda Environment Management Authority (2009). *Rwanda State of Environment and Outlook Report*. Kigali. https://www.rema.gov.rw/soe/full.pdf.

Rwanda Environment Management Authority (2011). *Green Growth and Climate Resilience: National Strategy for Climate Change and Low Carbon Development.* Kigali.

Rwanda Environment Management Authority (2019). *Assessment of Climate Change Vulnerability in Rwanda – 2018*. Kigali.

Rwanda Environment Management Authority (2021). Farmers Commend Silvopastoralism at Gishwati-Mukura National Park Settings. Milk production has increased since silvopastoralism approach was introduced in Gishwati rangelands. *SPIU Quarterly Newsletter Issue No 002 January - March 2021*, 2. Kigali. https://rema.gov.rw/fileadmin/templates/Documents/rema_doc/Newsletters/SPIU%20Newsletter%20--%20Issue%20No%20002.pdf.

Rwanda Ministry of Environment (2018). *FP073: Strengthening climate resilience of rural communities in Northern Rwanda.* Kigali. https://www.greenclimate.fund/sites/default/files/document/funding-proposal-fp073-ministry-environment-rwanda.pdf.

Rwanda Ministry of Environment (2020). *2019 Annual Performance Report for FP073: Strengthening Climate Resilience of Rural Communities in Northern Rwanda.*. Kigali. https://www.greenclimate.fund/document/2019-annual-performance-report-fp073-strengthening-climate-resilience-rural-communities.

Rwanda Ministry of Environment (2021). *2020 Annual Performance Report for FP073: Strengthening Climate Resilience of Rural Communities in Northern Rwanda.* Kigali. https://www.greenclimate.fund/document/2020-annual-performance-report-fp073-strengthening-climate-resilience-rural-communities.

Rwanda Water Resource Board (n.d.). *Terraces and filtration trenches*. https://waterportal.rwb.rw/toolbox/466. Accessed 13 December 2021.

Sanzua, L.J., Saha, H.M. and Mwafaida, J.M. (2019). Comparative evaluation of performance of commercial greenhouses in coastal humid climatic region of Kenya. *African Journal of Horticultural Science,* 15, 43-52. http://journal.hakenya.net/index.php/ajhs/article/view/34.

Saiz, G., Wandera, F.M., Pelster, D.E., Ngetich, W., Okalebo, J.R., Rufino, M.C. and Butterbach-Bahl, K. (2016). Long-term assessment of soil and water conservation measures (Fanya-juu terraces) on soil organic matter in South Eastern Kenya. *Geoderma*, 247, 1-9. https://doi.org/10.1016/j.geoderma.2016.03.022.

Sayer, J., Sunderland, T., Ghazoul, J., Pfund, J.L., Sheil, D., Meijaard, E. *et al.* (2013). Ten principles for a landscape approach to reconciling agriculture, conservation, and other competing land uses. *Proceedings of the National Academy of Sciences of the United States of America,* 110(21), 8349-8356. https://doi.org/10.1073/pnas.1210595110.

Siborurema, G. (2021). *Rwanda - AFRICA EAST - P131464 - Landscape Approach to Forest Restoration and Conservation (LAFREC) - Audited Financial Statement (English)*. Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/099115102152227387/LAFREC000Final0r0ended0300June02021.

Snelder, D., Kahimba, F., Korodjouma, O., Abebe, A., Oughton, E., Bunclark, L. *et al.* (2018). Adaptations in water harvesting technologies for enhancing food security and livelihood: A multi-country study in Sub-Saharan Africa. *Rainwater-Smart Agriculture in Arid and Semi-Arid Areas* [Leal Filho, W. and de Trincheria Gomez, J. (eds.)]. Cham: Springer International Publishing. 95-119. https://doi.org/10.1007/978-3-319-66239-8_6.

Staddon, C., Rogers, J., Warriner, C., Ward, S. and Powell, W. (2018). Why doesn't every family practice rainwater harvesting? Factors that affect the decision to adopt rainwater harvesting as a household water security strategy in central Uganda. *Water international*, 43(8), 1114-1135. https://doi.org/10.1080/02508060.2018.1535417.

Tomalka, J., Lange, S., Röhrig, F., Gornott, C. (2020). *Climate Risk Profile: Tanzania*. Bonn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://www.adaptationcommunity.net/wp-content/uploads/2021/02/GIZ_Climate-Risk-Profile-Tanzania_EN_final.pdf.

Trading Economics (2021). *Burundi Exports*. https://tradingeconomics.com/burundi/exports. Accessed 15 March 2022

Udawatta, R.P., Rankoth, L., & Jose, S. (2019). Agroforestry and Biodiversity. *Sustainability*, 11(10), 2879. https://doi.org/10.3390/su11102879.

United Nations Decade on Ecosystem Restoration (2021). *What is ecosystem restoration?* https://www.decadeonrestoration.org/what-ecosystem-restoration. Accessed 3 November 2021.

United Nations Environment Programme (2020). *Getting Climate-Smart with the Mountain Gorilla in the Greater Virunga Landscape:*

A Species and Climate Change Brief for the Vanishing Treasures Programme. Nairobi. https://www.grida.no/publications/532.

United Republic of Tanzania, Ministry of Natural Resources and Tourism (2017). *Environmental and Social Management Framework for the Resilient Natural Resources Management for Tourism and Growth Project*. Dar es Salaam. https://ewsdata.rightsindevelopment.org/files/documents/23/WB-P150523_kTCEpJM.pdf.

Wassie, Y.T. and Adaramola, M.S. (2019). Potential environmental impacts of small-scale renewable energy technologies in East Africa: A systematic review of the evidence. *Renewable and Sustainable Energy Reviews,* 111, 377-391. https://doi.org/10.1016/j.rser.2019.05.037.

Wei, F., Wang, S., Fu, B., Pan, N., Feng, X., Zhao, W. *et al.* (2018). Vegetation dynamic trends and the main drivers detected using the ensemble empirical mode decomposition method in East Africa. *Land degradation & development*, 29(8), 2542-2553. https://doi.org/10.1002/ldr.3017.

Wella, J. E. (2018). *Integrated Approaches for Climate Change Adaptation in the East Usambara Mountains.* Vantaa: NIRAS. https://knowledge4policy.ec.europa.eu/sites/default/files/factsheet_ongawa_tanzania.pdf.

Weinmann, S. (2018). *Impacts of Elephant Crop-Raiding on Subsistence Farmers and Approaches to Reduce Human-Elephant Farming Conflict in Sagalla, Kenya*. Graduate Student Theses, Dissertations, & Professional Papers. 11194. https://scholarworks.umt.edu/etd/11194.

White, J (2016) *Terracing practice increases food security and mitigates climate change in East Africa*. Climate Change, Agriculture and Food Security [CCAFS] (n.d.). https://ccafs.cgiar.org/news/terracing-practice-increases-food-security-and-mitigates-climate-change-east-africa. Accessed 15 March 2022.

World Bank (n.d.). *Tanzania: Resilient Natural Resource Management for Tourism and Growth*. https://projects.worldbank.org/en/projects-operations/project-detail/P150523. Accessed 13 December 2021.

World Bank (2013). *Project Appraisal Document on a Proposed Grant from The Global Environmental Facility Trust Fund in the Amount of US$4.2 Million to the Republic of Burundi for the Sustainable Coffee Landscape Project.* Washington, D.C. https://documents1.worldbank.org/curated/en/737101468019767768/pdf/758890PAD0P127010Box374377B00OUO090.pdf.

World Bank (2017). *Burundi Country Environmental Analysis: Understanding the Environment within the Dynamics of a Complex World – Linkages to Fragility, Conflict and Climate Change*. Washington, D.C. https://openknowledge.worldbank.org/handle/10986/28899. License: CC BY 3.0 IGO.

World Bank (2020a). *Landscape Approach to Forest Restoration and Conservation (LAFREC) (P131464)*. Implementation Status and Results Report. Washington, D.C. https://documents1.worldbank.org/curated/en/468971608156577907/pdf/Disclosable-Version-of-the-ISR-Landscape-Approach-to-Forest-Restoration-and-Conservation-LAFREC-P131464-Sequence-No-13.pdf.

World Bank (2020b). *Burundi Coffee Landscape Restoration and Resilience Project (P171745).* Washington, D.C. https://publicpartnershipdata.azureedge.net/gef/GEFDocuments/d78e1a4a-2297-ea11-a811-000d3a5c09ae/Roadmap/WBsPCNPIDPADISDSDecisionMeetingMinute_ID10594_PID%20ISDS%20P171745%20Apr%2030%20%282%29.pdf.

World Bank Group (2014). *Rwanda – Landscape Approach to Forest Restoration and Conservation*. Washington, D.C. http://documents.worldbank.org/curated/en/289491468108535843/Rwanda-Landscape-Approach-to-Forest-Restoration-and-Conservation.

World Bank Group (2019). *Burundi - Sustainable Coffee Landscape Project (English).* Washington, D.C. http://documents.worldbank.org/curated/en/134421557437468398/Burundi-Sustainable-Coffee-Landscape-Project.

World Biogas Association (2019). *Global Potential of Biogas.* London. https://www.worldbiogasassociation.org/wp-content/uploads/2019/09/WBA-globalreport-56ppa4_digital-Sept-2019.pdf.

World Meteorological Organization (2021). *State of the Climate in Africa 2020*. Geneva. https://library.wmo.int/doc_num.php?explnum_id=10929.

Wright, J.H., Hill, N.A.O., Roe, D., Rowcliffe, J.M., Kümpel, N.F., Day, M., *et al.* (2016). Reframing the concept of alternative livelihoods. *Conservation Biology* 30(1), 7-13. https://doi.org/10.1111/cobi.12607.

Yuliastuti, N., Wahyono, H., Syafrudin, S. and Sariffuddin, S. (2017). Dimensions of community and local institutions' support: Towards an eco-village kelurahan in Indonesia. *Sustainability*.9(2), 245. https://doi.org/10.3390/su9020245.

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The selected adaptation solutions portray cases and inspiration for achieving the United Nations 2030 Agenda for Sustainable Development and its 17 goals, especially Sustainable Development Goal (SDG) 5 on gender quality, SDG 6 on clean water and sanitation, SDG 13 on climate action, SDG 15 for life on land and SDG 17 on partnerships for the goals. Similarly to the SDGs, the solutions view different aspects of sustainable development and adaptation comprehensively, interconnected, and partly dependent on each other.

Beekeeping and honey production on the slopes of Rwenzori has improved the community livelihoods by reducing poverty among our communities especially for women who are producing honey for home consumption while the surplus is sold for income generation.

– Kasereka J. Muranga, Director of Rwenzori Mountains Development Association, Uganda

Participation of women in development issues and in making decisions in the village has increased, which is positive. In the Village Savings and Loan Association groups, women decide by themselves how to use the money, no one is telling a woman to do something.

– Halima Sheshe Idd, Acting Chairperson in the Mvambo village, Tanzania

With the help of Farmer Field Schools, we have been able to control the soil erosion through the use of contour lines and planting of trees. In the previous seasons, most of the crops were affected but with these techniques, productivity has increased.

– Margaret Nimbona, farmer in the Musigati community, Burundi