HOW CAN ENERGY ACCESS PRACTITIONERS ENERGISE REGENERATIVE AGRICULTURE SETTINGS?

APRIL 2023

RICHA GOYAL

ACKNOWLEDGEMENTS

The author is grateful to several individuals and organisations who generously shared data and insights, and enabled access to field work for the development of this work. These include, but are not limited to:

Coffee value chain
Daan Vreeburg, Agriterra
Shira Stites, Caroline and Antoine Jomand, PUR

Rice value chain
Anthony Mugambi and Andrew Cheboi, Kilimo Trust
Michael Mwangi, Chief Agronomist, Mwea Rice Growers Multipurpose Cooperative Society

Maize value chain
Assan Ngombe and Abednego Kiwia AGRA
Anthony Kioko, George Mabuka, Shadrack Kasonzo, Elijah Maithya and Lydhia Kiswii, CGA

Agro-pastoralists in Laikipia
Emily Franklin, Peter Wakahora and Augaly Kiedi, ReNature
Joseph Lentunyoi, Laikipia Permaculture Center

Horticulture value chain
Ralph Roothaert, World Vegetable Center

In addition, the author gratefully acknowledges Warren Bush (Quail Springs Permaculture), Sheena Shah (Permaculture Design Consultant & Educator), Nicholas Syano (Drylands Natural Resource Center), John Chettleborough (Practical Action), Arne Victor Garvi (Rewild Earth) and Fredrik Fredrick Ochieng (Biovision Africa Trust) for their valuable inputs.

The author would like to thank Jolanda van Ginkel and Nico Janssen from IKEA Foundation for their vision in bringing together interventions aimed at solarisation and regeneration of farmlands.

The author would also like to thank Anita Smith, Ellie Grebenik, Felicity Tolley, Jakub Vrba and Rachel Templeton (all Energy Saving Trust) and Michael Maina (CLASP) for their support in reviewing, copy editing and design.

IKEA Foundation

TABLE OF CONTENTS

ACKNOWLEDGEMENTS **2**

TABLE OF CONTENTS **3**

INTRODUCTION **4**

Regenerative vs more mainstream agricultural systems **4**

WHY IS IT IMPORTANT TO HAVE THIS CONVERSATION? **7**

1. Regenerative agricultural practices can de-risk solar product payments **7**
2. Carbon credits **8**
3. Regenerative agriculture – humanitarian settings – clean energy access nexus **8**

CASE STUDY APPROACH TO HELP ILLUSTRATE CLEAN ENERGY TECHNOLOGIES ACCESS IN REGENERATIVE FARMING SETTINGS **9**

Case study 1: Coffee cash crop value chain, Kericho **11**
General notes on coffee production in Kericho county, Kenya 12
Introduction to organisation(s)/initiative(s) 12
Farmers' experience with regenerative agriculture 12
Fertiliser economics 16
Role of solar technologies in the Kenyan coffee value chain 17
Case study 2: Rice value chain, Kirinyaga and Kisumu **22**
General notes on rice production in Kenya 23
Introduction to organisation(s)/initiative(s) 23
Farmers' experience with regenerative agriculture 23
Fertiliser economics 27
Role of solar technologies in the Kenyan rice value chain 28
Case study 3: Maize crop value chain, Makueni **35**
General notes on maize production in Kenya 36
Introduction to organisation(s)/initiative(s) 36
Farmers' experience with regenerative agriculture 36
Role of solar technologies in the maize value chain in semi-arid counties like makueni 39
Case study 4: Crop value chains suitable to arid and semi-arid (ASAL) regions **44**
General notes on crop value chains suitable to ASAL counties such as Laikipia 45
Introduction to organisation(s)/initiative(s) 47
Farmers experience with regenerative agriculture 47
Role of solar technologies and mechanical equipment in crop value chains in ASAL counties like Laikipia 48
Case study 5: Horticulture crop value chain, Murange and Kiambu **51**
General notes on vegetable production in Kenya 52
Introduction to organisation(s)/initiative(s) 52
Farmer experience with regenerative agriculture 53
Fertilizer economics – savings in input costs 53
Role of solar technologies in the traditional vegetables value chain 53

KEY RECOMMENDATIONS FOR HOW ENERGY ACCESS STAKEHOLDERS CAN ENERGISE REGENERATIVE AGRICULTURE SETTINGS **55**

INTRODUCTION

Productive use appliances powered by renewable technologies have direct impacts on user resilience. The type of agricultural system a farmer is embedded in has a big role in influencing the farmer's resilience and adaptation capacity and by virtue of that, has an indirect impact on the resilience that the farmer can gain by using solar appliances. Therefore, when energy access practitioners design interventions aimed at introducing solar technologies to farming systems, it is important that they are mindful of these interlinkages between farming systems, solar appliance access and farmer resilience.

This report uses five diverse case studies of crop value chains in Kenya to help document how energy access for farmers can be aligned with efforts aimed at transitioning farming systems to regenerative agriculture.

Regenerative vs more mainstream agricultural systems

While there is no universally accepted definition of regenerative agriculture, common practices used across existing definitions include no or minimum tillage, integration of livestock with crops, reduction in chemical inputs and crop diversification (through agroforestry, intercropping, crop rotations, or cover crops). These practices aim to deliver common outcomes of improved soil health, carbon sequestration, increased biodiversity, improved water resources, and increased social and economic well-being of communities[1].

On the other hand, more mainstream agricultural practices include but are not limited to excessive soil tillage, use of heavy farm machinery, monoculture cropping and unabated use of chemical inputs. Soil degradation on agricultural land is largely the result of prevailing (conventional) agricultural practices and associated environmental implications. The Food and Agricultural Organisation (FAO) estimates that human-induced soil degradation affects 34% of all agricultural lands[2] which has far-reaching implications for food security as 95% of human food is produced directly or indirectly on soils[3].

The prevailing conventional agriculture system is at odds with several sustainable development goals (SDGs), whereas regenerative agriculture is aligned with SDGs in the following ways:

1. Crop yield is linked with the following SDGs: SDG 1: No poverty, SDG 2: Zero hunger, SDG 8: Decent work and economic growth and SDG 12: Responsible consumption and production.

Loss in soil organic matter and soil degradation are consequences of mainstream agricultural practices and undermine the productivity of agricultural lands. Loss of soil organic matter and soil degradation undermines food productivity and is potentially contributing to increased food prices and/or increasing land expansion to meet food demand[4, 5]. Crop yields in well-designed regenerative organic systems have been shown to outproduce conventional yields for almost all food crops including corn, wheat, rice, soybean and sunflower[6].

[1] The Food and Land Use Coalition, Aligning regenerative agricultural practices with outcomes to deliver for people, nature and climate, (The Food and Land Use Coalition: 2023). https://www.foodandlandusecoalition.org/wp-content/uploads/2023/01/Aligning-regenerative-agricultural-practices-with-outcomes-to-deliver-for-people-nature-climate-Jan-2023.pdf

[2] Food and Agriculture Organization of the United Nations, The State of the World's Land and Water Resources for Food and Agriculture, Systems at Breaking Point, Synthesis Report 2021, 1.2. Human-induced land degradation, https://www.fao.org/3/cb7654en/online/src/html/chapter-1-2.html

[3] Food and Agriculture Organization of the United Nations, Healthy soils are the basis for healthy food production, February 2015, https://www.fao.org/soils-2015/news/news-detail/en/c/277682/#:~:text=It%20is%20estimated%20that%2095,turn%20nourish%20people%20and%20animals.

[4] Ghaley, Bhim., et al., Simulation of Soil Organic Carbon Effects on Long-Term Winter Wheat (Triticum aestivum) Production Under Varying Fertiliser Inputs, (Frontiers: Frontiers in Plant Science, 2018), https://www.frontiersin.org/articles/10.3389/fpls.2018.01158/full

[5] Oldfield, Emily., Bradford, Mark., and Wood, Stephen., Global meta-analysis of the relationship between soil organic matter and crop yields, (European Geosciences Union: SOIL, 2019), https://soil.copernicus.org/articles/5/15/2019/

[6] Moyer, Jeff., Smith, Andrew., Rui, Yichao., and Hayden, Jennifer., Regenerative Agriculture and the Soil Carbon Solution, (Rodale Institute, 2022), https://rodaleinstitute.org/wp-content/uploads/Rodale-Soil-Carbon-White-Paper_v11-compressed.pdf

2. Links with SDG 3: Good health and well-being

Perhaps the most direct adverse impact to health from mainstream agricultural practices is the use of agro-chemicals. World Health Organization's International Agency for Research on Cancer, has classified glyphosate, the most commonly and intensively used herbicide worldwide, as a probable carcinogen[7]. There is evidence to show that exposure to pesticides may increase the risk of diseases such as dementia, Alzheimer's, cancer, and other chronic conditions[8]. Conventional agriculture also contributes to air pollution and antibiotic resistance from antibiotics used in animal agriculture. There are also secondary effects on human health via water pollution and soil pollution, and wider effects on biodiversity. Conventional practices like monocropping also undermine nutritional diversity leading to several nutritional deficiencies[9].

3. Positive climate effects in regenerative farming have links with SDG 13: Climate action

The prevailing food production system has been a leading factor in the world's crossing of six of the nine planetary boundaries: climate change, land use system change, biosphere integrity, biogeochemical flows, freshwater change and novel entities[10]. The current food production system is dominated by unsustainable and environmentally harmful farming practices[11], and is a leading cause of greenhouse gases (GHG), biodiversity loss, agro-chemical pollution and soil degradation[12].

In contrast, regenerative practices such as agroforestry, intercropping, crop rotations, reducing chemical inputs, and holistically managed grazing have a positive effect on climate change mitigation. More work is needed to quantify both carbon sequestration and GHG emissions from regenerative farming systems, but the existing evidence shows that regenerative farming does not have significant negative effects on carbon sequestration, and that crop diversification, reducing chemical inputs and tillage, and more holistic livestock management are good options for increasing the carbon sink potential of farmlands[13, 14].

4. Links with SDG 6: Clean water and sanitation, and SDG: 15 Life on land

20% of synthetic nitrogen and phosphorus fertilizers are lost through runoff; they bio-accumulate in rivers and oceans and even on land, leading to eutrophication.

Globally, approximately 600 deltas and coastal areas suffer from seasonal anoxia driven by Nitrogen and Phosphorus contamination, approximately 80% of which originates from food production. ~80% of large marine ecosystems have been subject to eutrophication, leading to algal blooms and deoxygenised dead zones. Farmers in Africa and India use river water for domestic consumption, the same river waters that have been contaminated by agro-chemical inputs.

---

[7] International Agency for Research on Cancer, Evaluation of five organophosphate insecticides and herbicides, (International Agency for Research on Cancer: IARC Monographs Volume 112, 2015), https://www.iarc.who.int/wp-content/uploads/2018/07/MonographVolume112-1.pdf

[8] Moyer, Jeff., et al., The Power of the Plate, The Case for Regenerative Organic Agriculture in Improving Human Health, (Rodale Institute, 2020), https://rodaleinstitute.org/education/resources/power-of-the-plate-regenerative-organic-agriculture/

[9] Ibid.

[10] Campbell, Bruce., et al., Agriculture production as a major driver of the Earth system exceeding planetary boundaries, (Ecology and Society, 2017), https://www.ecologyandsociety.org/vol22/iss4/art8/

[11] 'Currently, only 1.5% of the world's agricultural land is farmed organically'. Global Agriculture, Global organic crop area countries to grow, report, 2020, https://www.globalagriculture.org/whats-new/news/en/33932.html#:~:text=Currently%2C%20only%201.5%25%20of%20the,%25

[12] Crowder, David., and Reganold., John, Financial competitiveness of organic agriculture on a global scale (PNAS, 2015), https://www.pnas.org/doi/10.1073/pnas.1423674112

[13] The Food and Land Use Coalition, Aligning regenerative agricultural practices with outcomes to deliver for people, nature and climate, (The Food and Land Use Coalition, 2023). https://www.foodandlandusecoalition.org/wp-content/uploads/2023/01/Aligning-regenerative-agricultural-practices-with-outcomes-to-deliver-for-people-nature-climate-Jan-2023.pdf

[14] Moyer, Jeff., Smith, Andrew., Rui, Yichao., and Hayden, Jennifer., Regenerative Agriculture and the Soil Carbon Solution, (Rodale Institute, 2022), https://rodaleinstitute.org/wp-content/uploads/Rodale-Soil-Carbon-White-Paper_v11-compressed.pdf

Regenerative farming, on the other hand, reduces or eliminates chemical inputs and leads to enhanced biodiversity via crop diversification, both domesticated and non-domesticated. It also increases the number of mobile pollinators such as bees[15].

[15] Lichtenberg, Elinor., et al., A global synthesis of the effects of diversified farming systems on arthorpod diversity within fields and across agricultural landscapes, (Global Change Biology, 2017), https://onlinelibrary.wiley.com/doi/10.1111/gcb.13714

Given the many co-benefits of regenerative agriculture and their potential alignment with several SDGs, the question arises about whether energy access practitioners should consider embedding themselves in regenerative agricultural contexts. This report is a starting point in this conversation and is by no means conclusive. More evidence is needed to help inform the interlinkages and synergies between solar-based productive use in agricultural settings and type of agricultural system. Furthermore, this question does not mean that energy access practitioners should not also enable energy access in mainstream forms of agriculture. Currently, organic farming only forms 1-2% of global farming systems although it is gaining more traction, driven by various interest groups and policy-led interventions[16]. As global farming practices shift to more climate smart, sustainable agricultural practices, farmers, irrespective of the farming system they are part, will continue to need support in gaining access to energy.

There are several synergies linking productive use appliance access and regenerative agricultural efforts:

1. Regenerative agricultural practices can de-risk solar product payments

Ability to assess credit worthiness in a nimble manner and consumer bankability are critical known barriers for making end-user financing available at scale for purchase of solar technologies. Farmers practising regenerative farming practices are cushioned against some of the risks that a farmer practicing a high chemical input-based monocropping farming faces. This reduction in risk occurs in the following manner, in turn helping improve the credit worthiness of the farmer who needs to access finance for purchasing solar technologies.

- Higher crop yields: As mentioned previously, crop yields in well-designed regenerative organic systems have been shown to outproduce conventional yields for almost all food crops including corn, wheat, rice, soybean and sunflower[17]. Case study 3 on maize crop value chain in Makueni county, Kenya, describes a steep improvement in yield and a reduction in input costs as farmers started growing maize based on regenerative principles.

- Reduction in input cost: Since the early 2020s there has been a significant surge in synthetic fertilizer prices in African countries as well as everywhere else owing to several macro-economic events such as an increase in input prices, supply disruptions due to sanctions in Russia and Belarus, and China's restrictions on the export of fertilizers[18]. This has helped improve cost parity of fertilizers in favour of organic inputs such as compost. A simplistic calculation of cost parity between natural vs synthetic fertilizers are presented in case studies for coffee, rice and horticulture in the next section. In many cases, use of natural pesticides and lower reliance on pesticides and herbicides in regenerative farming settings also helps bring down input costs.

- Higher resiliency in the face of pest attacks: Recently in Kenya, locust attacks and fall armyworm (FAW) attacks have been especially disruptive. Farmers resort to using expensive and toxic chemicals, which also increases farming input costs. Toxic residues remain on the crops and in some cases makes the yield unfit to consume or contaminates water sources. FAW thrives better under drought conditions, and the Kenyan drought in 2016-2017, which affected most of the country, spurred this infestation further. FAW does not seem to thrive as well with long rains and the Kenyan FAW infestation cycle was finally broken when the long

[16] Willer, Helga., Trávníček, Jan., Meier, Claudia., and Schlatter, Bernhard., The World of organic agriculture - STATISTICS & EMERGING TRENDS 2022, (IFOAM and FiBL, 2022), https://knowledge4policy.ec.europa.eu/publication/world-organic-agriculture-statistics-emerging-trends-2022_en

[17] Moyer, Jeff., Smith, Andrew., Rui, Yichao., and Hayden, Jennifer., Regenerative Agriculture and the Soil Carbon Solution, (Rodale Institute, 2022), https://rodaleinstitute.org/wp-content/uploads/Rodale-Soil-Carbon-White-Paper_v11-compressed.pdf

[18] Baffes, John., and Chian Koh, Wee., Fertilizer prices expected to remain higher for longer (Data Blog, 2022), https://blogs.worldbank.org/opendata/fertilizer-prices-expected-remain-higher-longer

rains happened in 2018[19]. It can be argued that, in certain contexts, a changing climate is increasing pest infestation; temperature is a dominant abiotic factor affecting herbivorous insects like FAW[20]. Regenerative farming techniques such as crop diversification, healthier soils, and integrating plants and animals on farms, are making farming systems naturally more resilient to pest infestations compared to monoculture cropping systems.

Combining the above listed aspects implies that farmers following regenerative agricultural practices are likely to have higher disposable incomes, which could be used to invest in various assets. This could include investments in solar technologies to boost farm productivity further. More evidence is needed to confirm this hypothesis.

2. Carbon credits

Currently there are several efforts underway in the energy access sector to quantify emissions reductions based on decentralised solar technologies and use these measurements to issue carbon credits[21, 22]. Many of the gains in emissions mitigation from solar technologies can be eroded by emissions in an intensive mainstream farming system.

On the other hand, carbon sequestration and GHG mitigation opportunities from regenerative farming systems can potentially be combined with GHG mitigation benefits from using decentralized solar technologies to boost monetization via carbon credits.

3. Regenerative agriculture – humanitarian settings – clean energy access nexus

In Kenya, tens of thousands of hectares of farmlands have become so degraded that they no longer produce adequate or regular crops or pasture for livestock. Reduced precipitation and climate variability will mean that farmers will be able to practice less and less rainfed agriculture. It is projected that by 2050, as many as 38.5 million people in East Africa will be internally displaced due to climate issues[23]. This displacement will add stress to humanitarian settings which are already overwhelmed. Regenerative agriculture practices have the potential to reduce displacement by making the farmlands more productive. In the energy access sector, enabling access to clean energy in humanitarian settings is an emerging area of focus, and regenerative agriculture can help provide some relief both to reduce climate-linked displacement and to provide livelihood support in humanitarian settings.

Figure 1: People in informal settlement of internally displaced people in Somaliland. Image from https://time.com/6110836/african-climate-migration-world-bank/

[19] Waruru, Maina., Fall Armyworm attack: Desperation pushes Kenya Farmers to Danger (Down to Earth, 2019), https://www.downtoearth.org.in/news/agriculture/fall-armyworm-attack-desperation-pushes-kenya-farmers-to-danger-63525

[20] Yan., Xiao-Rui., et al., Impact of Temperature Change on the Fall Armyworms, Spodoptera frugiperda, under Global Climate Change, (MDPI: Insects, 2022)., https://www.mdpi.com/2075-4450/13/11/981

[21] For example, the CarbonClear programme: https://persistent.energy/investee/solstroem/

[22] Kumar, Ashish., and Patel, Anshul., Digitising and unlocking climate finance for the off-grid sector, (Shell Foundation: Opinion, 2020), https://shellfoundation.org/opinion/digitizing-unlocking-climate-finance-for-the-off-grid-sector/

[23] Dungy, Dee., Climate change and forced displacement in Eastern Africa, (Jesuit Refugee Service, 2022), https://jrs.net/en/news/climate-change-and-forced-displacement-in-eastern-africa/

CASE STUDY APPROACH TO HELP ILLUSTRATE CLEAN ENERGY TECHNOLOGIES ACCESS IN REGENERATIVE FARMING SETTINGS

The recently published paper by AGRA on sustainable farming practice in sub-Saharan Africa[24] articulates the role of participatory watershed management principles in rehabilitating degraded land and conserving water, and the importance of integrating renewable energy systems in sustainably managed farming systems. However, the paper largely speaks to an agricultural specialist audience and more work is needed to build the capacity of energy access specialists who may wish to work within regenerative agricultural systems. There is no precedence or guidance on enabling access to solar off-grid appliances in regenerative agricultural contexts and how, if at all, this work could be different to that of enabling access in conventional agricultural settings. A case study approach was therefore developed for this report, involving documenting key regenerative agriculture efforts being undertaken in Kenya across diverse crop value chains and agro-ecological contexts, see Table 1: Details of crop value chains covered under this study. This data was then used to propose key appliance categories that can help enhance the resiliency and reduce drudgery of farmers undertaking regenerative agricultural practices within these crop value chains. An approach for how these specific groups of appliances could be integrated within the crop value chain while causing the least level of unintended consequences was developed in a consultative manner through discussions with farmers and organisations working on regenerative agricultural principles.

This study covers a non-exhaustive but diverse sample of farmer groups/organisations involved in regenerative agriculture in Kenya to help illustrate the most impactful ways in which energy access stakeholders can embed themselves within regenerative agricultural interventions.

The case study approach involved conducting key informant interviews and focus group discussions. This allowed the collection of information from a range of people including agricultural specialists, operations personnel of respective organisations working to capacity build farmers using regenerative agricultural techniques, cooperative and society members, farmers undertaking regenerative agriculture and members of applicable farmer support organisations.

The crop value chains (and their respective counties) that were covered as part of this study are detailed in Table 1. The case study approach was further supplemented by a detailed literature review. Unless a reference is provided, the insights in the report are informed by:

1. Key informant interviews and focus group discussions with smallholder farmers and other stakeholders involved in the value chains mentioned in Table 1; and
2. The author's own analysis from the aggregated data.

Table 1: Details of crop value chains covered under this study

CROP VALUE CHAIN	ORGANISATIONS UNDERTAKING REGENERATIVE AGRICULTURE INITIATIVES	COUNTIES
Coffee	Agriterra, ReNature & PUR	Kericho
Rice	Kilimo Trust	Kirinyaga
Maize	AGRA & CGA	Makueni
Agro-pastoralists & native semi-arid species	ReNature	Laikipia
Horticulture (vegetables)	World Vegetable Center & SNV	Muranga and Kiambu

[24] Amede, Tilahun., Konde, Aggie Asiimwe., Muhinda, Jean Jacques., and Bigirwa, George., Sustainable Farming in Practice: Building Resilient and Profitable Smallholder Agricultural Systems in Sub-Saharan Africa, (MDPI: Sustainable Agriculture, 2023), https://www.mdpi.com/2071-1050/15/7/5731

To propose a set of clean energy technologies that can help enhance the impact of regenerative farming practices, it is imperative to view the crop value chain in question through a regenerative farming lens. This lens should be used to determine which solar technologies are needed and if their implementation mechanism should be different from that in conventional agricultural settings. Questions considered include, for example:

- Could there be technologies that help scale organic fertilizer production?
- How can the implementation model of solar irrigation technologies be different so as to allow the integration of water harvesting principles, such that farmer resiliency is enhanced during prolonged drought period?
- Should efficient cookstoves be an important component of enabling productive use appliance access to smallholder farmers as this helps prevent trade-off with agro-forestry (reduction in firewood demand)?

Such insights can emerge only if understanding of regenerative farming principles is applied in a solar technology needs assessment exercise. For this reason, the case studies below first describe the regenerative farming aspects of the crop value chain, and use this assessment to make a recommendation of the most suitable set of solar technologies.

Case study 1: Coffee cash crop value chain, Kericho

General notes on coffee production in Kericho county, Kenya

Kericho county lies within the breadbasket of Kenya, in the Rift Valley region. Its characteristics, such as adequate rainfall, cool climate and fertile soils, have made it an important contributor to Kenya's urban food supplies and a foreign exchange earner by way of agricultural produce exports[25]. The two main cash crops in Kericho county are tea followed by coffee.

Farmers tend to produce either coffee or tea (rather than both) and enrol with coffee and tea cooperatives as appropriate. While a small number of large-scale coffee production houses may act independently, most small-scale coffee farmers are organised under farmer cooperatives and societies.

While other sub-counties also have substantial portions of the crop, in Kericho county, coffee is grown majorly in Kipkelion West sub-county. The total crop area in Kericho county is approximately 2,000 Ha. The coffee production area is increasing as more farmers in the coffee zones are adopting this crop or increasing the area of farmland under coffee production.

However, over the last three decades, rainfall has become irregular and drought more frequent, deteriorating the county's agricultural output, including its coffee production[26].

Introduction to organisation(s)/initiative(s)

The situation of deteriorating crop output owing to unpredictable climatic conditions prompts the question of whether growing coffee with regenerative agricultural techniques could be an important tool to help enhance farmer resiliency. Two key initiatives linked to growing coffee with regenerative techniques in Kericho county are being independently led by Agriterra/ReNature and PUR. Agriterra and ReNature (both Dutch organisations) in partnership with Moyee Coffee, Fairchain Foundation, KALRO and Kipkelion District Cooperative are working on the development and implementation of a regenerative coffee farming system designed for maximum carbon uptake in biomass and soil. The project's underlying objectives include increasing food security, farmer income and resilience to the impacts of climate change.

PUR's work seeks to restore and sustainably manage the coffee ecosystem initially via a pilot project in Cherara cooperative, Kericho. The aims of the project include providing support to farmers through agro-forestry, Good Agricultural Practices (GAP) and improved cookstoves. The field work undertaken during this study aimed to document Agriterra and ReNature's efforts and investigate the various types of solar technologies that could help enhance their work with farmers further.

Combined insights from field sites under both initiatives are presented in the following sub-sections.

Farmers' experience with regenerative agriculture

Types of regenerative agricultural practices being followed by PUR and AgriTerra:

- Agroforestry – Agroforestry consists of growing trees around or among crops, to provide numerous ecosystem services such as preventing soil erosion, promoting soil regeneration, diversification of revenues, etc. In the context of coffee farming, agroforestry could include intercropping coffee with trees that provide shade alongside other benefits. Avocados and banana trees work quite well as shade trees for coffee

[25] Anyango, Anita., Kericho in Kenya exports Sh110M coffee to South Korea, (Farmers Review Africa, 2022), https://farmersreviewafrica.com/kericho-in-kenya-exports-sh110m-coffee-to-south-korea/#:~:text=Coffee%20is%20the%20second%20most,portions%20of%20the%20cash%20crop.

[26] Biwott, Kezia., Kericho County: Tea, Foods and Shifting Weather Patterns, (The Elephant, 2022), https://www.theelephant.info/op-eds/2022/09/16/kericho-county-tea-foods-and-shifting-weather-patterns/

crops while providing revenue diversification.

- Establishment of nursery at society level and providing training on nursery management. A nursery is vital not just for providing healthy saplings of the cash crop in question but also helps integrate agroforestry. The nurseries being managed at society level with support from PUR and AgriTerra include a healthy diversity of tree species such as moringa, avocado, two types of coffee including ruiru 11, grevillea, Cordia Africana, Croton Macrostachyus, Sesbania, spathodea, markhamia lutea, jacaranda, cypress, acacia, neem, bridelia and fruit trees like guava, papaya. These trees provide several benefits including food, timber, firewood, and mulch.

- Cover crops: Farmers are now intercropping coffee with nitrogen-fixing fodder crops for animals which also serves the dual purpose of covering crops. These crops include calliandra and sesbania.

- Organised and centralized compost production at community level; wet milling of coffee cherry is often done at a community level. Normally leftover coffee pulp from wet milling processes is dumped openly, where it releases methane from decomposition, a potent greenhouse gas. Its runoff also pollutes local rivers. By organising compost production at a community level, coffee pulp can be converted to compost and emissions from its decomposition can be reduced.

Figure 2: Nursery at Cherara Society supported by PUR, Kericho. The nursery has a healthy mix of coffee and a variety of indigenous and fruit tree saplings

Farmer respondents under this study reported that as a result of aggregating compost production, water quality around communities have started to improve. There are other forms of agricultural waste in Kericho that, if aggregated, could make it a hub for compost production while reducing toxic pollution and environmental emissions.

- One of these is the leftover coffee husk produced during the dry milling process. See image A, Figure 3.
- Sugarcane is among Kericho's most important cash crops[27]. After harvest, sugarcane stumps are typically burnt to remove dry leaves and drive off snakes and other rodents. Burning cane fields releases large amounts of nitrogen and other toxic particulate matter, increasing air pollution in cane-growing regions.

Aggregation of such types of agricultural waste that are otherwise causing pollution and emissions at farm level can help boost quantities of compost production, which in turn helps boost soil health and provide further carbon sequestration benefits.

[27] Raballa, Victor., West Valley Sugar firm seeks to set up Sh800m factory in Kericho County, (Nation, 2021), https://nation.africa/kenya/business/-west-valley-sugar-firm-seeks-to-set-up-sh800m-factory-in-kericho-county-3618400

Image 3A: Coffee husks during dry milling at Kipkelion W. Cooperative

Image 3B: Burning of sugarcane stumps in Kericho

Figure 3: Other types of agricultural waste in Kericho county

Transition phase from conventional to regenerative practices

In Kenya, coffee yield per tree is generally low, with Kipkelion West having an average of 4 –12 kgs[28] per tree while the rest of the county records 2 – 3 kgs per tree against a potential of over 30 kgs per tree[29]. As a conventionally-managed farm transitions to regenerative practices, crop yields and therefore farmer incomes initially decline, until a balance in the system is reached. These transitions can take up to three years, sometimes more, depending on how depleted the soil and farming system is at the start.

Post transition phase, coffee cherry output is expected to improve to at least20 kg cherry output per tree in the Kipkelion W. sub-county. A 3–5-year transition period is expected given additional challenges from a changing climate.

Improvements noticed by farmers in crop fields during transition phase

Farmers report an improvement in soil health shown by an increase in organisms such as worms in soil, and improvement in soil pH health[30] as demonstrated by soil testing results and increase in size of leaves and stems of fodder crops. Farmer reliance on chemical inputs has also reduced; farmers need less weedicides and other sprays. In the past, farmers typically needed to do three weed sprays in a single year, the 1st spray in March, the 2nd spray in June, and the 3rd spray in September. Now, farmers have adopted the practice of weed slashing[31], and instead spray just once a year.

Fertiliser economics

Since the early 2020s there has been a significant surge in synthetic fertilizer prices owing to several macro-economic events such as an increase in input prices, supply disruptions due to sanctions in Russia and Belarus, and China's restrictions on the export of fertilizers[32]. This helped improve cost parity between fertilizers and organic inputs such as compost. Table 2 summarises the difference between cost of synthetic fertilizer and compost in quantities that are being used by farmers practicing regenerative practices per (coffee) tree, per year. Using compost is cheaper by 17 Kenyan shillings per tree per year, approximately 30% cheaper than using synthetic fertilizers as a percentage. These savings could be increased further if compost production is undertaken at scale at cooperative level. As a result of the interventions by AgriTerra or PUR, compost is being produced at the coffee societies where these organisations are active in Kericho county. The Kimologit Society in Kipkelion W. is currently producing 720 bags of compost a month (1 bag of compost is 50kg) and they have plans to expand compost production to 1200 bags/month. It takes them about three weeks' to prepare one batch of compost.

At a usage-rate of 4 kg of compost per coffee tree per year, 80 bags of compost are required per 1000 trees. Given the abundance of coffee and sugarcane agricultural waste in Kericho county, see images in Figure 3, this level of compost production can be achieved if mechanisms for aggregation of agricultural waste products could be organized at community and cooperative level. Solar technologies such as chaff cutters and solar furnaces can play an important role in producing organic fertilizers such as compost and biochar at scale.

[28] Data from interviews conducted during this research.
[29] Muriithi, Lucy., Viability of Coffee Farming As a Business. (Kenya Agricultural & Livestock Research Organization, 2016), https://www.kalro.org/sites/default/files/2016-Coffee-ruiru-fair-presentation-LUCY.pdf
[30] Farmers reported that soil pH value changed from 4.5 as indicated by a test conducted early in the year 2021 to 6.0 – 7.0 in January 2022.
[31] Slashing weeds also adds mulch to the soil and is a suitable practice for small farm holdings due to reduced labour requirements.
[32] Baffes, John., and Chian Koh, Wee., Fertilizer prices expected to remain higher for longer (Data Blog, 2022), https://blogs.worldbank.org/opendata/fertilizer-prices-expected-remain-higher-longer

Table 2: Comparison of cost of synthetic fertilizer inputs vs compost (organic fertilizer) input in small scale coffee farming in Kericho county, Kenya.

ITEM	AMOUNT (PRICES ARE INDICATED IN KENYAN SHILLINGS OR KSH)
Amount of NPK* put in 1 coffee tree/year	250 gms
Cost of NPK post-price increase**	6000 KSH/bag (4000)
Amount of CAN*** put in 1 coffee tree/year	300 gms
Cost of CAN post-price increase	4500 KSH/bag (2100)
Cost of 50 kg compost bag	500 KSH
Amount of compost put in 1 coffee tree/year	4 kg
Cost of NPK per tree	30 KSH
Cost of CAN per tree	27 KSH
Total cost of chemical fertilizer per tree/year	57 KSH (with pre-increase prices this would have been ˜33 KSH)
Cost of compost/tree	40 KSH

*These three numbers form what is called the fertilizer's N-P-K ratio — the proportion of three plant nutrients in order: nitrogen (N), phosphorus (P) and potassium (K).
**Comparison is being done using increased fertilizer prices in 2021 – 2022
***Calcium ammonium nitrate

Role of solar technologies in the Kenyan coffee value chain

Creating a service-based hub model for regenerative agricultural services and solar technologies access

Farmer groups such as agricultural societies, cooperatives or various other mechanisms, help provide meaningful aggregation and appropriate market linkages. Provision of solar technologies that require a certain level of aggregation across farmer groups for reasons such as economic viability, inventory management constraints and other logistical reasons, could piggyback on existing infrastructure for provision of agricultural inputs. A central location such as the premises of the local communities, cooperative or other agricultural support organisations such as the offices of the agricultural extension service officers, could be used to provide access to solar technologies based on servitisation models. Servitisation models help ease logistical issues typically associated with keeping repair processes affordable and can help reduce solar appliance downtime and maintenance costs per user. There could be further benefits such as time-use efficiencies by avoiding the need for farmers to have to travel to multiple locations to access various services.

Technologies could include: irrigation services based on community models, agricultural processing services and cold storage (to the extent this is possible given the need for proximity between market access and installation site of cold storage units). A nursery that integrates indigenous tree saplings with the seeds and saplings of the primary commercial crop in question, could also be combined in such a hub model. Such nurseries can help boost agro-forestry, a key aspect of regenerative farming practices. Based on the inputs provided by the farmers of the coffee societies interviewed as part of this study, the following list of services was compiled that was deemed most impactful if provided at the level of a farmer aggregation body.

Irrigation and agricultural processing requirements:

1. Maize thresher: Almost all farmers use a portion of their land for growing maize for self-consumption and sale of surplus production. Maize thresher is often run by petrol. Farmers usually hire these machines for a fee,100 Kenyan shillings to shell one sack or 90 kgs of maize. A petrol/diesel free alternative for a centralized threshing service could be explored.

2. Water harvesting training center combined with solar pump access: From the lens of enhancing regenerative farming practices, it would not be sufficient to provide access to solar pumps alone. It would be important to combine rain water harvesting measures alongside enabling access to pumps. Coffee society premises in Kericho county are built over at least 1 – 1.5 acres of space. Simple water harvesting structures can be built across the society premises to capture all rainwater which can be stored and pumped for use in wet milling and nursery management. Generally speaking, rain water harvesting is only done on the roofs of built structures, but this leaves large parts of the land where rainwater simply runs off carrying with it topsoil and nutrients. Harvesting water across the land using simple earthwork structures would help substitute some of the pumping demand that is currently met from surface water bodies such as rivers. In order to alleviate issues related to drudgery in carrying over long distances and security related issues, coffee nurseries are often located near rivers, if feasible. At the level of societies, there is a need to install adequate water storage solutions like tanks, ponds etc. A solar pump can then be used to re-distribute water from a storage/rainwater catchment system to nursery beds and wet milling needs, and extract water from surface water bodies or underground water sources as back up. Units like this can also serve as water harvesting demonstration points for farmers, and would be a good way to make a start towards mainstreaming water harvesting practices in farmlands.

3. Nursery with access to solar pumping: This would combine coffee tree saplings, indigenous tree saplings and fruit tree saplings to help diversify farmer income and help improve farmer food security. Nurseries require irrigation two times a day every day, except during rainy seasons, and a solar pump is the most efficient method to ensure steady supply of water to the nursery.

4. Wet mill with solar water pump: Wet milling in Kericho county is an energy and water intensive process. The Torochmwai society, one of the smaller coffee societies in Kericho where pulping is done for nine months a year, spent 54000 Kenyan shillings on petrol in 2021 to mill 49000 kgs of cherries. Approximately 43000 litres of water were used in this process for pulping and washing the beans. The Charara society spent approximately 160000 shillings on 1500L of diesel in a single year for wet milling 550000 kgs of cherries. These estimates vary between societies, increasing or decreasing based on the size of society and the type of technologies deployed in the wet milling process. The single most important intervention that can reduce use of petrol and water, and bring savings to farmer groups, would be to solarise the wet mills and the water pumping process.

- Solar dryers: Almost all coffee societies use natural methods of drying (direct sunlight) using wooden beds. Usually, wood for constructing beds comes from grevillea trees and wood for poles comes from acacia trees.

- Inputs:
    - Timber need: According to the Cherara coffee society staff members, building 1 foot of dryer-bed requires approximately 1 kg timber. The size of a typical wooden dryer is 1m in width and 30m in length, and all dryers need to be replaced every year. Given that a grevillea tree takes 10 – 15 years to mature, this is significant demand for timber. See Image A, Figure 4.
    - Cost: Total cost of building a wooden dryer per year per bed is approximately 4000 Kenyan shillings[33]. In Cherara society alone, there are 79 beds that require 7505 feet of timber and ˜320000 Kenyan Shillings as dryer replacement cost per year.
- Improvement in output with solar dryers: One wooden dryer can dry 71-72 kg of coffee parchment[34]. 6 kgs of coffee cherry yields approximately 1 kg of parchment. These wooden bed-based dryers, that simply use atmospheric temperatures from drying, are inefficient both in terms of economic and labour cost as well as high timber needs. If a solar dryer were to be installed, drying time can be reduced significantly as cherries do not need to be covered, allowing them to dry quicker. Also, the solar dryer will reduce the time-consuming process of removing and covering exposed cherries during rains and intense sunny periods etc. The drying process is even, and the quality of parchment is improved. While there are several different kinds of solar dryers, solar tunnel dryers are low-cost and well suited for this value chain. In solar tunnel dryers, only the outer polythene sheet needs to be replaced every five years. They also require less repair. Beds are made of metal and are less prone to rusting as compared to wooden beds where the wire mesh gets rusted easily. See Image B, Figure 4.

[33] This estimate does not include the cost of wire mesh which does not need replacement on a yearly basis.

[34] Parchment coffee is an intermediate stage in the process of preliminary processing of coffee beans.

Image 4A: Rows of wooden dryers for naturally drying coffee parchment

Image 4B: Solar tunnel dryer alongside wooden dryers with rusted wire mesh

Figure 4: Coffee parchment drying in Kericho County

Other needs:

<u>1. Compost point with chaff cutter:</u> Chaff cutters are useful for both chopping animal feed and producing compost at scale to be able to meet organic fertilizer needs for all society members. See image in Figure 5.

<u>2. Efficient cookstoves:</u> Almost all farmers use open fire or firewood-based cookstoves. Using efficient cookstoves would reduce demand for wood, which in turn would reduce the strain on forests and sustain agro-forestry on farmland. This would also save time in firewood collection. According to the coffee farmers in Kericho, on average, a single family can spend up to three hours at a time collecting firewood. Approximately 5-7 kgs of firewood is required for a family of seven per day.

<u>3. Community TV for the youth and others alike:</u> This could help bring the community together and enable a space for sharing ideas. Loads like TVs can be powered by the excess power generated from water pumping sets when they are not in use. TV watching over an organised schedule could attract people to the community space and encourage interest in the interaction between solar technologies and regenerative agriculture.

Figure 5: Image of a fossil fuel-based chaff cutter being deployed for aggregated compost making, Kericho county

Case study 2: Rice value chain, Kirinyaga and Kisumu

General notes on rice production in Kenya

Rice is the third most important cereal crop in Kenya after maize and wheat in terms of calorific consumption. The rate of consumption increase per year for rice is much below its growth in yield. Kenya is only able to fulfil up to 30% of demand locally[35] and imports the remaining rice from other rice producing nations such as Thailand, Vietnam, Pakistan and India, and an additional small amount of imports from neighbouring East African countries[36].

Kenya has ambitious goals to boost domestic yields and substitute rice imports with local production. In Kenya, the majority of rice production (approximately 80%) is from irrigation schemes (canal system) implemented by the National Irrigation Authority and the remaining is rain-fed. The objective of Kenya's National Rice Development Strategy (NRDS)[37] Phase II (2019 – 2030) is self-sufficiency and increased paddy rice production from 156,000 in 2018 to 1,301,000 MT by 2030. A range of interventions including reducing cost of production, improved access to credit, climate adaptation, post-harvest management and market linkages are needed to help achieve these goals.

Introduction to organisation(s)/initiative(s)

Kilimo Trust is a not-for-profit organisation working on the topic of 'agriculture for development' across the East Africa community. In one of their projects, they are working with rice cooperatives in Kirinyaga and Kisumu counties. Kirinyaga and Kisumu are the highest rice producers among Kenyan counties. Kilimo Trust's interventions, among other things, involve building the capacity of rice societies to undertake regenerative farming techniques. The following sub-sections cover insights particularly from the Mwea Rice Growers Multipurpose Co-operative Society Ltd (MRGM) in Kirinyaga county. MRGM is part of the Mwea Irrigation Scheme, which is the largest irrigation scheme in the country. There is potential to increase this scheme by an additional 10,000 acres.

MRGM is based on a unique business model that minimises lending risk to farmers while enabling access to important agricultural services on credit. Provision of services is across the crop value chain and includes land preparation, rotavating, disk ploughing, levelling, seeds, transplanting, farm inputs, harvesting and transport of the paddy to the mill. Cash advances to the farmers are given in such a manner that the total member exposure does not exceed 70% of the paddy delivered to the cooperative. The farmer can go to the local bank to get funding in the form of crop advance. This is subtracted from the credits previously given to farmers by the cooperative.

Farmers' experience with regenerative agriculture

Rice farming in Kenya is predominantly based on floor irrigation implemented via irrigation schemes developed by the National Irrigation Authority (NIA). Floor irrigation may not allow scope for regenerative techniques such as intercropping or agro-forestry, but MRGM are working with Kilimo Trust to make the farming production more sustainable through the following practices:

- Impact of use of synthetic chemicals in rice production and use of bio-based inputs like biochar:
  Since water availability is limited, a scheme of water sharing is being implemented based on an irrigation-sharing schedule. Intermittent flooding and draining of water is undertaken across farmer fields divided in different groups. Since the same water is flooded and then drained, the water also carries with it any agro-chemical residues used by farmers. Chemical laden water bioaccumulates around farmlands of downstream farmers the most, and some farmers have even reported instances of the

[35] Ndirangu, Samuel Njugana., and Oyange, Wilson., Analysis of Millers in Kenya's Rice Value Chain, (ISOR Journal of Agriculture and Veterinary Science, 2019), https://journals.indexcopernicus.com/api/file/viewByFileId/454595.pdf

[36] Mwea Rice Growers Multipurpose, Public Case Report, August 2020 (The Sustainable Trade Initiative, 2020), https://www.idhsustainabletrade.com/uploaded/2020/11/200828_MRGM-Case-Final-Public-Report.pdf

[37] An initiative borne out of the Coalition for Africa Rice Development (CARD)

disappearance of fish around August in downstream river areas. Farmers often dispose of agro-chemicals in plastic or metal containers which eventually end up in the river as well. There are also instances of hyacinth blooms (a common aquatic weed seen in polluted water bodies) in drainage canals. Furthermore, many farmers in the downstream region are engaged in horticulture. The agro-chemicals can potentially leach into the soil and plants in the downstream region whether or not horticulture farmers intended it, and finally end up on food plates. Phasing out the use of synthetic fertilizers and supplementing organic fertilizers like biochar will be important in making rice production less environmentally harmful. Kilimo Trust and MRGM have taken important steps to develop biochar production from rice husks, a waste product from rice milling. See Figure 6. Renewable energy-based carbonisation systems can play an important role in scaling biochar production.

Image 6A: Rice husk hill as a by-product from milling at Mwea Rice Growers Multipurpose Coop

Image 6B: Small scale rudimentary system for biochar production

Figure 6: Bio-char production from rice husk, Mwea sub-county, Kirinyaga County, Kenya

- Ducks and golden apple snail:
    - Golden apple snails (figure 7) are an invasive pest in Kenya, first reported at the Mwea Irrigation scheme in 2020. If farmland is not drained well after the first flooding before rotavating, any remaining small puddles create an environment for snails to thrive. Ducks that feed on the snails can damage the rice transplants. A single snail can wipe out 1 square meter of farmland overnight. Snails and ducks together can cause 80% damage to transplants.
    - The easiest way to control golden apple snails is application of synthetic molluscicides, which have adverse impacts on the environment, non-target species, and human health[38].
    - While there is no direct link between access to solar technologies and this pest, an indirect link does exist. To ensure farmer resilience and de-risk solar payments in rice value chains, capacity building farmers to use ecological principles in management of snails (as opposed to use of synthetic 'instant kill' molluscicides) is key, as well as ensuring effective draining to prevent puddles forming in the first places.

Figure 7: Apple snail eggs (pink) in Mwea, Kirinyaga county. Image from Nation Africa Kenya Edition https://nation.africa/kenya/business/seeds-of-gold/apple-snails-causing-kenya-s-basmati-rice-to-lose-its-aroma-study-reveals-3766512

[38] Schneiker, Janina., et al., Is there hope for sustainable management of golden apple snails, a major invasive pest in irrigated rice?, (Science Direct: NJAS - Wageningen Journal of Life Sciences, 2016), https://www.sciencedirect.com/science/article/pii/S1573521416300343

- Farming calendar, quelea birds and crop rotation:
    - Usually farmers produce rice three times a year, in the main season between August – December, a ratoon crop between February – March and the third off-season crop between March – June/July. This does not allow time for crop rotation. Furthermore, ratoon crops attract greater levels of infestation by quelea birds. In Kenya, about 25% of grains are lost to quelea birds. The latest quelea invasion in Kisumu County destroyed 300 acres of rice fields and threatens another 2,000 acres during the harvest season[39]. A single bird can feed 40 – 80 gms of rice/day and a single swarm can have millions of birds. The Ministry of Agriculture has tried poisonous aerial spray at the breeding sites to kill the birds, but their numbers continue to grow due to their quick breeding rate. Migratory birds interbreed with local birds and therefore poisoning these birds can have a negative impact on the whole ecosystem. An approach that balances use of technology such as use of machines that imitate the distress sounds of birds and using regenerative farming principles in pest management needs to be developed in a consultative manner with regenerative agriculturists. See sub-section 'birds and grains' under Case study 3: Maize value chain.
    - Ecosystem service payments to incentivise farmers to not grow second (ratoon) or third crops of rice, and instead practice rotational cropping with legumes that would have other co-benefits would help immensely. To explore this further, Kilimo Trust in collaboration with MRGM and Egerton University are conducting randomized controlled trials to test yield increase in farmlands substituting ratooning with legume based rotational cropping.

Fertiliser economics

Kilimo Trust is working with farmers via the MRGM to convert rice husks, waste from rice milling, to biochar and use this as a lower cost and healthier alternative to synthetic fertilizers. See image A, Figure 6.

Using biochar in soils as a mechanism for long term carbon sequestration and soil amendment has been identified as a way to combat climate change[40].

Based on inputs from MRGM, if rice farmers were to switch from synthetic fertilisers to biochar-based organic fertilizer, five bags of biochar available at a rate of 2400 KSH/ bag would be required each year per acre of farmland. This results in a total cost of 12000 KSH/ acre as opposed to 16750 KSH/ acre for synthetic fertilisers, see Table 3. Before the recent fertiliser price increase, a complete switch to biochar would have increased farmer input cost by at least 50%. However, with the price increase, the economics of biochar production with respect to synthetic fertilisers has improved greatly. In the year 2022, when this data was collected, the cost of synthetic fertilisers for both planting and top dressing amounted to approximately 16750 KSH/ per acre, 40% more than using biochar-based fertilizer alone.

[39] Wangira, Dorcas., Kenyan rice farmers battle quelea birds in Kisumu, (BBC News: 2023), https://www.bbc.com/news/world-africa-64596927
[40] Intergovernmental Panel on Climate Change, Climate Change 2022, Mitigation of Climate Change, Summary for Policymakers, (IPCC: 2022), https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SPM.pdf

Table 3: Economics and scale of biochar production at MRGM

ECONOMICS AND SCALE OF BIOCHAR PRODUCTION AT MRGM	AMOUNT
Weight of 1 bag of rice	100 kg
Proportion of rice husk in 1 bag of rice	40%
Proportion of biochar	20%
Total amount of rice production under Mwea irrigation scheme	1 million rice bags
Bags brought to MRGM for milling	10% or 100000 bags
Bags brought to private millers	Remaining 90%
Total bags of rice husk MRGM can consolidate annually	40000
Total bags of biochar MRGM can consolidate annually	20000
# of biochar bags needed for 1 acre farm land per year	5 bags
Price of 1 bag of biochar	2,400
Total input cost/acre	12000

Currently, Kilimo Trust and MRGM are in early stages of perfecting a biochar production and use model. 1-2% of the active farmer base of MRGM have adopted the use of biochar and started to phase out use of synthetic fertilisers. Training is required to increase biochar adoption and gradual change in farmer behaviour is expected over the course of 2-3 years. There is also the issue of competing use-cases for biochar. Biochar can be used as a low-cost filler or to bring down the carbon footprint of production of other materials and products like furniture and cement[41]. Any intervention aimed at scaling production and use of biochar as fertilisers will need to evaluate competition from competing use cases. Renewable energy can play an important role in developing suitable pyrolysis methods for producing biochar.

Role of solar technologies in the Kenyan rice value chain

Rice farming is the most mechanised form of farming in Kenya and therefore it is one of the value chains where a high level of renewables, including a highly diverse range of solar based appliance integration is possible. A list of farm equipment and technologies that can benefit from solarisation are mentioned below. This list was aggregated based on inputs from Kilimo Trust and MRGM staff members and smallholder rice farmers.

Potential for electric tractors

- Farmers currently use diesel tractors for land preparation and harvesting. The

[41] Suarez-Riera, Daniel., Restucia, Luciana., Ferro, Guiseppe., The use of Biochar to reduce the carbon footprint of cement-based materials (Science Direct: Procedia Structural Integrity, 2020), https://www.sciencedirect.com/science/article/pii/S2452321620304315

main types of tractor implements used by farmers include rotavators with crawlers, levelers, ridgers, disc ploughs, combine harvesters and trailers. Currently in Kenya, some research is being undertaken to determine the potential for transplanters that are suitable for Kenyan soils. MRGM offers tractors to farmers on a rental basis. The cooperative has access to tractors from New Holland, USA and Kumbota, Japan, that were acquired with the help of a loan given to the Kenyan government by the Japanese government.

- Use of tractors across various services can result in a big fee and large fuel consumption leaving significant opportunity to explore the potential for electric tractors. 1 acre can require up to 18L of diesel or 4000 KSH/acre for rotavating and levelling services and another 4000 - 5000 KSH for combine harvesting.

- It is recommended that a techno-economic feasibility assessment is undertaken for use of electric tractors that the cooperative could own, and offer to the farmer on a service-based model. Rising fuel costs and environmental pollution related to use of diesel-based tractors help make the case for a lightweight electric tractor. Based on inputs from an electric tractor manufacturer in India, the smallest garden tractor in India consumes 3-4L of diesel per hour of use and larger (50 – 60 HP) tractors, or more energy intensive services, could consume as much as 8-10L. This is compared to an electric tractor which can consume as low as 4-5kWh. The savings realised from the reduction of fuel cost over the lifetime of an electric tractor could be shared with farmers, hence lowering their input costs and increasing profit margins.

Pests and potential application of solar powered bird sound maker

- Quelea migratory birds are a particular menace in Sub-Saharan Africa. In Kenya, about 25% of grains are lost to these birds. In addition, significant input costs are incurred to station manpower, often as a full day time job, to drive the birds away, see image A, Figure 8. As noted previously, the latest quelea invasion in Kisumu County destroyed 300 acres of rice fields and threatened another 2,000 acres during the harvest season[42].
- Machines that imitate the distress sounds of birds can potentially help drive away the destructive birds. Further research is needed to identify ecosystem friendly mechanisms for keeping birds away. Efforts are being undertaken under the Capacity Development Project for Enhancement of Rice Production in Irrigation schemes in Kenya (CaDPERP) programme to develop a locally manufactured machine.
- Image B, Figure 8 shows a model of a machine called Bird Pro imported from China by Nyanon Enterprises. As this machine is suitable for farm sizes of 1 acre, a single machine can be combined with amplifiers or multiple machines can be trialed based on group ownership and rent-to-own models.

[42] Wangira, Dorcas., Kenyan rice farmers battle quelea birds in Kisumu, (BBC News: 2023), https://www.bbc.com/news/world-africa-64596927

Image 8A: Several humans stationed to scare away quelea birds

Image 8B: Solar powered bird scaring machine, Bird Pro imported from China. Price: 40000 KSH (˜400 USD) inclusive of import duties and taxes.

Figure 8: Use of technology in managing quelea birds. Location Nyabon Enterprises, Kisumu County

Retrofitting existing milling and drying capacity with solar energy

- Overview of rice mills in Kenya: The findings of the study on rice milling in Kenya, undertaken by the Jomo Kenyatta University of Agriculture and Technology and Ministry of Agriculture, Livestock, Fisheries and Irrigation, Kenya, year 2019 indicate that there are about 16 medium and large mills with a total installed capacity of 66 tonnes/hour across the mills. 256 small-scale millers were also identified, with an estimated capacity of 128 tonnes/hour.[43] These electric mills are powered using the utility grid or diesel. There is potential to explore retrofitting these rice mills with solar power.

Figure 9: Mwea town area dotted with private rice millers, Kirinyaga county

[43] Ndirangu, Samuel Njugana., and Oyange, Wilson., Analysis of Millers in Kenya's Rice Value Chain, (ISOR Journal of Agriculture and Veterinary Science, 2019), https://journals.indexcopernicus.com/api/file/viewByFileId/454595.pdf

Notes on current scenario of milling and drying undertaken by MRGM:

- MRGM's milling machine is among the larger mills in Kenya with a capacity of 3 tonnes of rice/hour, and is powered by the Kenyan utility grid. MRGM incurs a monthly electric bill of *at least* 4M KSH/month from milling alone. Typical power outage is between 3-4 hours per day. Despite the outages, they do not rely on diesel back-up and are able to mill 8 hours a day. See image A, Figure 10.
- Rice drying in MRGM: The cooperative has both a drying yard, for drying directly under the sun, and electric dryers. During the wet/cold season, between June – July, regular sun drying is not effective. The time taken to dry under the sun is 4-6 hours on a sunny day and space is also a constraint. The cooperative has two drying units, each with capacity to dry 130 bags or 13 tonnes of rice at a time, with each cycle taking around 3-4 hours depending on moisture content. See image B, Figure 10.

Image 10A: Electric milling at MRGM

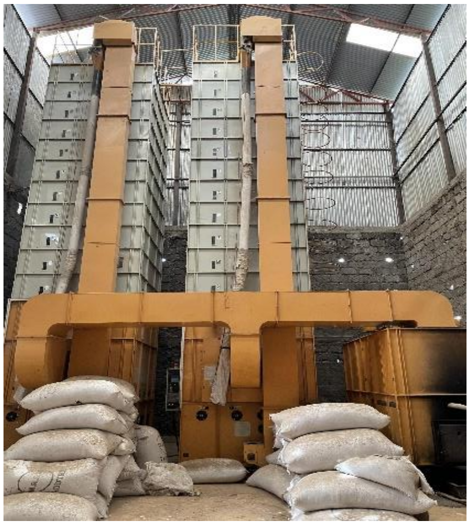

Image 10B: Electric drying units at MRGM

Figure 10: Electric milling and drying at MRGM

Solarising milling capacity: To support the goals of Kenya's National Rice Development Strategy (NRDS) Phase II (making Kenya self-sufficient in its rice production) growth in production needs to be supported by increasing the capacity and efficiency of the rice milling industry. Solarising milling can play a key role in improving the economics of milling. In the energy access sector, there have been efforts to integrate mini-grids with milling loads, but the demand for the initial surge in current drawn by turning on a large mill, has meant that it has not always been economically feasible. In the case of MRGM and other larger rice mills in Kenya, the main source of energy supply is from the utility grid rather than diesel generators. Some of the previous work in clean energy access for milling machines has focussed on smaller milling machines with a throughput of few 100kgs and/or in cases where they are being powered by diesel generators[44]. MRGM's milling machine is larger with a throughput of 3 tonnes/ hour, and uses the Kenyan national utility grid as its primary energy source. Moreover, there is a consistent and predictable yearly demand for milling. There is a clear case for exploring an economic feasibility assessment of retrofitting large-scale rice milling with a dedicated solar rooftop and using the findings of such an exercise to develop a plan for solarising rice milling.
MRGM incurs an annual electricity bill of 6-7M KSH from milling and drying which prevents it from taking steps to improve the infrastructure of the cooperative in order to improve the paddy intake to rice output ratio. It is recommended that an economic feasibility assessment is undertaken to explore retrofitting the milling and drying capacity in the cooperative with solar power. MRGM is one of 16 medium and large rice mills present in Kenya and is undertaking several innovative steps in sustainable rice production. The cooperative can serve as an example to demonstrate best practices in energy management to other rice millers in the country. MRGM requires expansion of both milling and drying capacity, and solarisation of potential expansion of capacity can also be explored in such an exercise.

If rice cooperatives could retrofit existing mills with solar panels, their cost of milling could come down compared to those who do not use the technology, such as private millers, though a detailed cost benefit modelling exercise will need to be undertaken to compare monthly utility tariffs with the transition to solar energy. There would be several co-benefits from undertaking solarisation of mills if this is deemed economically feasible. It is estimated that after completing payback on capital costs of retrofitting, the solarisation of mills and dryers can result in annual electricity savings of 6-7M KSH. These savings can be invested back into improvements such as:

- Constructing perimeter (safety) wall for hoarding stores to improve security.
- Expanding the drying yard
- Cementing floors to control moisture and recover any rice spillage.

Lack of simple measures like these leads to loss of at least 1% of yield, or 1000 bags worth of rice. See images in Figure 11. Undertaking these measures will increase profit, which will ultimately be transferred back to the farmers as they are part of a cooperative model. These savings can also be undertaken to boost further regenerative agricultural efforts.

[44] Dougherty, Jane., Lovin, Erika., and Davies, Gabriel., Milling on Mini-Grids: How Africa's Largest Crop Could Go Diesel-Free, (Next Billion, 2020), https://nextbillion.net/milling-on-mini-grids-africa-maize/

Figure 11: Spilled rice cannot be recovered because of lack of flooring, MRGM premises, Mwea, Kirinyaga

Case study 3: Maize crop value chain, Makueni

General notes on maize production in Kenya

Maize is a staple food crop for most Kenyans. It is a rainfed crop and any change in its production level is closely linked to Kenya's food security. Almost every farmer retains a small part of their farmland for production for self-consumption and sale of surplus yield. In Kenya, maize yield declined by 13% between 2021 and 2022 due to climate related factors such as unreliable rainfall and drought, increased temperatures and related events[45]. According to the Kenya Food Security Steering Group (KFSSG), the maize harvest in marginal agricultural areas reduced to 45-50 percent of the five-year national maize production average[46].

In this context, while integrating solar technologies in maize value chains, energy access practitioners could explore differences in farmer resilience and maize yield levels across different types of agricultural systems. Could farmer resilience be enhanced if energy practitioners embedded themselves in regenerative agricultural efforts?

The following sections detail insights from maize grown using regenerative principles in Makueni county, in a programme implemented by AGRA with the Cereal Growers Association (CGA), and offer insights into what a joint programmatic effort to energise the maize value chain and to grow maize using regenerative agricultural principles could look like.

Introduction to organisation(s)/initiative(s)

AGRA, in partnership with the IKEA Foundation, is collaborating with CGA and Farm Africa to implement a project in Makueni and Embu counties that seeks to promote regenerative practices in maize farming. The project specifically aims to contribute to food security and to building sustainable market-led agriculture systems that meet the needs of local communities while contributing to national development goals[47]. This case study focuses on the work undertaken by AGRA and CGA in Makueni county.

Makueni has several different agro-ecological zones and slightly different corresponding crop value chains. It is divided into highlands, midlands and lowlands. Maize and pigeon pea are grown across all zones. Farmers who can access irrigation irrigate fruit trees and vegetables.

Farmers' experience with regenerative agriculture

With support from AGRA and CGA, farmers have adopted the following key regenerative farming techniques.

- Crop rotation with legumes.
- Intercropping cereals and legumes.
- Mulching.
- Fencing to prevent overgrazing by livestock.
- Agro-forestry and development of nurseries to provide tree seedlings to farmers.
- Minimum tillage practices such as ripping and zai pits. Zai pits are small hollows in which seeds of annual or perennial crops are planted, see image in Figure 12.
- Rainwater harvesting measures[48], the key one being zai pits. Zai pits improve water efficiency by retaining rainfall within the pits

[45] Mutiso, Juvenalis., and Kimtai, Aldrine., Climate Change and Maize Production in Kenya: Adaptation Options, (The Kenyan Institute for Public Policy Research and Analysis: Policy Brief, 2023), https://repository.kippra.or.ke/bitstream/handle/123456789/4028/PB22-2022-23.pdf?sequence=1&isAllowed=y

[46] Kenya Food Security Outlook, Widespread Crisis (IPC Phase 2) outcomes following third consecutive below-average season, (FEWS NET, 2022), https://fews.net/sites/default/files/documents/reports/KENYA_Food_Security_Outlook_Feb%202022_National%20Outlook_Final.pdf

[47] AGRA, Regenerative Agriculture Compendium, (AGRA, 2021), https://agra.org/wp-content/uploads/2021/11/AGRA_Regenerative_Agriculture_Compendium_TK02_Single-Pages_v5.pdf

[48] Makueni is a semi-arid county and it is common for people to harvest roof water. Some farmers also have ponds, which were built by the National Irrigation Authority. AGRA/CGA also encourage farmers to build ponds and soil/water structures such as terraces. With recent droughts, these measures have proved insufficient and greater levels of rainwater harvesting strategies such as zai pits need to be adopted.

and minimising moisture loss. Cover crops are also planted along with the maize inside the pits to prevent further moisture loss and provide nitrogen.

These practices have resulted in significant reductions in input costs and improvement in maize yields.

- Farmers have been able to reduce their input costs:
    - By focussing application of fertilizers in zai pits and reducing wastage.
    - By focussing application of seeds in zai pits. Previously, farmers simply cast the seeds and now they put them in the zai pits or bunds. This has reduced the amount of money spent on seeds by at least 50%.
- Farmers reported improvement in maize yields:
    - Farmer's input costs have decreased by 20- 30 % while maize crop yields have increased from 1 – 3.3 bags per acre to 6.7 – 10 bags per acre depending on the season.
    - The biggest contributor to increased crop yields are zai pits and intercropping/crop rotation with legumes, more than the phase out of synthetic fertilizers. While CGA allows micro-dosing of synthetic fertilizers during the transition period from conventional to regenerative farming techniques as opposed to an outright ban, few farmers have continued to use chemical inputs at the same rate and their yields have improved regardless. This is because droughts are a key factor limiting yields; zai pits in combination with legumes acting as cover crops significantly help improve water availability to maize crops.

Figure 12: Zai pits in a Village Based Advisor's farm during the planting season of November 2022 (image provided by AGRA).

There is an indirect link between building farmer resiliency with regenerative farming practices and a farmer's credit worthiness for solar payments. More studies need to be undertaken to test this hypothesis and build an appropriate evidence base to inform solar energisation interventions in agricultural contexts. In this case, Zai pits play an important role in increasing yields, cushioning produce against drought, and reducing cost of inputs like seeds and fertilizers - all these factors make the farmers more resilient and likely to be able to bear the cost of (and benefit from) a solar appliance over time.

Birds and grains

Birds are one of the key threats to any cereal crop. There are examples of farmers who have resorted to using plastic covers on maize crops as a protective measure against birds, which increases aflatoxin build-up[49] in the seeds. See image in Figure 13.

Figure 13: Coping strategy by farmers of covering millets/grains with plastic as a protective mechanism against bird predators. This image shows a sorghum crop. Farmers are known to use a similar practice for maize.

[49] Kenya has one of the highest levels of aflatoxin concentrations in maize in the world.
Lewis, Lauren., et al., Aflatoxin Contamination of Commercial Maize Products during an Outbreak of Acute Aflatoxicosis in Eastern and Central Kenya, (National Center for Biotechnology Information: Environ Health Prospect, 2005), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1314917/

Birds preying on cereals is also one of the reasons why many farmers have reduced millet and sorghum production. Millets are a robust dryland crop, and many millet species are inherently drought tolerant. In a climate where rainfall is increasingly erratic and extended drought periods in semi-arid regions are a new normal, the case for increasing millet production is becoming strong. To encourage millet production, and to reduce losses in maize farming from birds, it is vital to address the issue of birds feeding on cereal crops using pro-ecological methods.

A combination approach involving natural and technological solutions like bird repelling machines (see discussion in sub-section 'Pests and potential application of solar powered bird sound maker' under Case Study 2: Rice value chain) must be developed in a consultative manner with regenerative agriculturists. Due to the technical nature of the discipline, energy access practitioners remain at a risk of only using a technology-led approach. There is a chance that in conventional farming settings, energy practitioners working in silos will adopt approaches involving technical solutions, such as bird scarers, alone. However, if energy and regenerative farming experts work together, alternative and more inclusive approaches such as those illustrated below are possible.

- Using agro-forestry techniques to provide a home for birds within crop lands: When planning agroforestry, it is important to think about planting trees and plants of varying heights that are a mix of tall grasses, dense shrubs, trees with tall canopies and thorny plants/trees like acacia that provide a safe haven for birds from extreme temperatures, hot sun, rain, and predators. This can be done in a small portion of the farm to direct the birds away from the cereal crop.

- Other approaches such as bird netting, scare eye balloons and bird repelling machines may need to be combined with agro-forestry. There are examples of regenerative agriculture practitioners who have provided a safe environment for birds while protecting their crops by netting two thirds of cash crops, while leaving one third of them un-netted for the birds. There are seasons when farmers have lost up to 70% of their crop due to bird invasion, but planning a dedicated crop for birds can significantly help cut losses.

Role of solar technologies in the maize value chain in semi-arid counties like makueni

1. Machines to help build and scale water harvesting structures.

   Energy access stakeholders need to evaluate the appliances that are required to build and scale water harvesting structures quickly in the face of prolonged droughts, see images in Figure 14. These could include:

- Tractor implement for ripping: Ripping is mainly done to break the hard pan of the soil during dry season. There is a lack of suitable and available service providers for implements for ripping. In general, access to efficient electric tractors for farmers to rent could help with transport-related services like pulling water tankers, transporting hay and other commodities.

- Machines for digging zai pits: Off the shelf technologies such as electric jack hammers could make the labour-intensive task of digging earth less intensive. An appropriate customized, electrically-powered machine could also be designed using input from farmers that could dig up to 1m depth and remove the soil. Farmers who were interviewed for this study reported that it took 4 farmers working on average for 3 days a week over a period of 4 months to dig zai pits in a 1-acre farm manually. On the other hand, half an acre of zai pits can be dug in 1 day using an electric digging machine.

Image 14A: Example of an electric jack hammer

Image 14B: Ripper, tractor implement

Figure 14: Machines to help build and scale water harvesting structures

2. Solar water pumps: Readily available water is vital for many tasks. In Makueni County, many farmers grow fruit trees and vegetables which require irrigation and there are also livestock and domestic needs. Furthermore, NIA has built over 145 ponds in Kat ward, Makueni. Pumps are needed to efficiently distribute water from these ponds.

   When using SWPs in a region that is prone to droughts, it is important to combine rainwater harvesting (RWH) practices with a pump intervention. This will help ensure that surface water (as applicable) and groundwater tables are recharged, ensuring a sustainable supply of water for pumping by farmers. When policy makers consider enabling access to pumps for irrigation, it is also important to take a long-term view on whether water access will be available to a farmer. There is a need to plan holistic solutions for access to pumping that combine bundled services including the following elements:

   - capacity building farmers involved in regenerative farming practices to help them implement rainwater harvesting strategies in their farms. This would include both capturing and storing rainwater.
   - financing plans for solar water pump
   - financing plans for storage solutions like tanks or ponds. Some feedback that emerged strongly during this Focus Group Discussion was that farmers would like financing to be made available to build ponds and have this combined with a pump intervention. For many farmers the cost of financing a pond themselves is prohibitive, as is the cost of installation of good quality tanks and pipes.

Image 15A: Example of a tank installed under tree shade to help improve life of the storage tank

Image 15B: Example of a pond dug by NIA in a farmer's field

Figure 15: Examples of storage solutions for water

3. Technologies to help reduce food waste:

- Cold storage: It is vital to integrate fruit trees with farms in a changing climate as they help diversify incomes and provide food security. Perishability is the biggest barrier to generating income from fruit production. The biggest wastage occurs during the ripening season when the fruits are abundantly available; ˜20 – 25% of fruits and vegetables are wasted in Makueni.

  Figure 16 shows the price of mango fruit across its season. The price drops sharply in January – February period where maximum wastage occurs as mangoes are ripening everywhere and farmers are forced to offload their produce or let it go to waste because there is more supply than demand in the market.

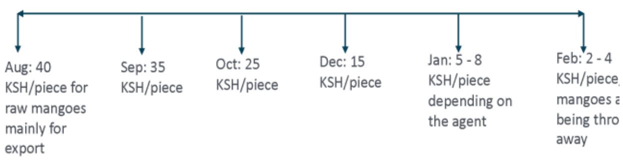

Figure 16: Timeline for price of mango fruit across its season

- Solar dryers for fruit: If every farmer had access to solar dryers, they could dry fruit for self-consumption and sale instead of throwing away fruit. Cold storage solutions will not completely eliminate food waste. Drying technologies can serve as an important complementary solution that can also help with farmer nutritional security. Any intervention aimed at enhancing uptake of drying technologies for self-consumption of fruit needs to be combined with an intervention aimed at raising awareness on nutrition and importance of diet diversity. Farmers can be upskilled to build do-it-yourself small-scale solar dryers, see Figure 17.

Figure 17: Image of an early prototype of a DIY solar dryer

4. Other technologies:

- Milling/shelling machines for maize
- Improved cookstoves to help reduce trade-off with agro-forestry and reduce deforestation

Case study 4: Crop value chains suitable to arid and semi-arid (ASAL) regions

General notes on crop value chains suitable to ASAL counties such as Laikipia

Arid and Semi-Arid Lands (ASALs) are defined by their aridity levels; annual rainfall ranges between 150 mm to 550 mm for arid areas and between 550 mm to 850 mm for semi-arid areas. There are high rates of evapo-transpiration with high temperatures all year round. In Kenya, ASAL makes up 80% of the landmass, and is home to approximately 36% of the population, 50% of the counties, 70% of the national livestock herd and 90% of wildlife[50].

The main types of livelihoods in the ASAL regions are pastoralism, agro-pastoralism, mixed farming, marginal fixed farming and some irrigated cropping. The IPC Acute Food Insecurity and Acute Malnutrition Long Rains analysis of ASAL counties in Kenya conducted between July and August 2021[51] found that an estimated 2.1 million people in the ASALs are experiencing high levels of acute food insecurity. This was a 34% increase on the same period the previous year. Key causes of this food insecurity are failed rains, low agricultural production and high food prices. In general, the population in the ASALs is very food insecure due to high levels of poverty, high vulnerability to shocks and hazards, and the aridity and rainfall variability of the areas.

The ASALs have incredible plant biodiversity and, if effectively maintained, this could feed livestock yearlong. However, due to mismanagement and overgrazing, ASAL productivity has declined. Now, many ASALs are dominated by less desirable herbaceous and woody plant species (that are less compatible with the agro-economic zone) and in some areas, desirable plant species have disappeared[52].

Lack of dietary diversity is a key reason for chronic malnutrition and addressing hunger by counting calorie consumption is not sufficient to address nutritional deficiencies. A quarter (26%) of Kenyan children under 5 presented with stunted growth in 2014, and this number is much higher in rural pockets, e.g. 46% in Kitui and West Pokot counties[53]. A diverse diet can only be achieved by access to crops from diverse crop lands. Furthermore, there are risks in relying on just a few plant species to feed the population. When a disease starts spreading in a particular crop variety, the entire value chain can be disrupted. Climate change is also threatening the ability to grow staple crops such as wheat, maize, soy and rice in many locations because of greater droughts, flooding and rising temperatures.

In the ASALs, particularly where rainfall is erratic, it may not be wise to introduce crops that would rely on extensive artificial irrigation. It is important to promote and develop commercial value chains of edible and medicinal plant and tree varieties that are naturally adapted in these regions and are hardy against drought conditions. Many of these species have now disappeared or been forgotten and could be categorised as neglected food/orphan crops/ indigenous food/future foods/cinderella species, all synonymous terms used by various organisations. These foods constitute the bedrock of the diversity in traditional and indigenous food systems and energy technologies could enable more effective growth of these foods in ASALs.

---

[50] State Department for the ASALs and Regional Development, Frequently Asked Questions, What are the ASALs?, (Ministry of East African Community, The ASALs and Regional Development, accessed April 2023), https://www.asals.go.ke/faqs

[51] Ingrated Food Security Phase Classification, IPC Acute Food Insecurity and Acute Malnutrition Analysis, Kenya - ASAL, (IPC, 2021), https://www.ipcinfo.org/fileadmin/user_upload/ipcinfo/docs/IPC_Kenya_Acute_Food_Insecurity_Malnutrition_2021Jul2022Jan_Report.pdf

[52] Kirwa, Everlyne., Characterization of Selected Range Grass Species in the ASALs of Kenya, (KALRO Kiboko ARLRI, 2017), https://www.kalro.org/asal-aprp/node/19

[53] Kenya National Bureau of Statistics, et, al., Kenya Demographic and Health Survey, (Kenya National Bureau of Statistics, 2014). dhsprogram.com/pubs/pdf.fr308/fr308.odf

Image 18A: Livestock is a bigger hazard than climate change and wildlife to soil erosion because of overgrazing. Bare soils increase runoff from rainfall making deep gullies, leading to even more runoff

Image 18B: Sacks of charcoal kept for sale. Firewood needs for cooking compound the problem. Often, an old acacia tree is cut to make ½ a bag of charcoal.

Image 18C: Pastoralists are adopting coping strategies such as buying hay from neighbouring counties like Meru. At the time of this site visit, April 2022, there had been no rainfall in 8 months. 1 bale of hay costs 280 KSH. 1 bale feeds 3 cows, this is only used as survival supplement and is not full diet.

Figure 18: Overgrazing, deforestation and soil erosion in ASAL, Kenya

Introduction to organisation(s)/initiative(s)

reNature Foundation & Investments from the Netherlands is working with Laikipia Permaculture Centre (LPC) in Nanyuki, Kenya to implementing a project focussed on regenerative agro-forestry with a goal to creating and spreading an agroforestry system to adapt to climate change, regenerate soil, and increase farm resilience. This case study includes insights from the field sites of this project in Laikipia county.

reNature is working on a multi-faceted strategy to tackle the issues described above, involving the following elements:

- Payments for ecosystem services approach to keep farmers from chopping down acacia and other trees. This could be in the form of carbon credits by measuring additionality in biomass by tree growth.
- Managed grazing by mobile fencing to rotate grazing pastures.
- Providing alternative livelihoods or diverse income generation strategies so pastoralists do not have to make charcoal for a living.
- Developing indigenous crop value chains and using solar technologies within those to optimise productivity.

Farmers experience with regenerative agriculture

reNature and LPCs approach in Laikipia is rooted in agro-forestry, or, farm level adoption of carefully selected tree species from the catalogue of indigenous tree species in Kenya maintained by Kenya Forestry Research Institute (KEFRI).

Their focus is on adoption of trees that:

- Provide food: introduction of fruit trees for nutrition security and fibre e.g. mango, avocado, passion fruit, etc.
- Trees that provide fodder during dry season: This involves introduction of nitrogen-fixing plants and various types of acacia trees that are especially useful to pastoralist communities. Examples include leucaena, sesbania, mulberry, faidherbia etc. Faidherbia, or white acacia, exhibits reverse phenology i.e. it sheds leaves during the wet season and produces them during dry season, making it particularly useful for pastoralists in drought periods. Many pastoralists in Laikipia have had to buy fodder bundles from neighbouring counties as a coping mechanism during extended periods of drought, see image 3 in Figure 18, and growing these types of trees could reduce this requirement.
- Trees that promote nature-based enterprises like honey production i.e. trees that promote forage for bees. Examples include acacia mellifera.
- Trees that provide fuel wood, such as gravillea.
- Trees that help promote soil conservation, such as bamboo (holds soil tight), vetiver grass.

reNature and LPC are following slightly different approaches in Laikipia depending on regional rainfall levels across the county.

- In the western part of Laikipia, where rainfall is slightly higher, reNature is developing an approach, in partnership with Rabobank, to develop carbon credits to support additional growth in trees in a model where 80% of proceeds goes to farmers.
- In northern Laikipia, which is drier, their approach focuses on creating commercial value chains around plants such as aloe vera, opuntia stricta and others that thrive in arid conditions.

A hectare of land can grow as much as 4000 plants of aloe vera, intercropped with legumes and trees like acacia and grevillea. Aloe vera is ready for harvest within 6 months of planting and can be harvested every 3 months as it is perennial. LPC has been capacity building Masai women to make toiletries such as soaps, shampoos, shower gels, body lotions and aloe tea from aloe vera plants.

Figure 19: Image showing natural biodiversity in arid regions: aloe vera plants, acacia tree and cacti.

Role of solar technologies and mechanical equipment in crop value chains in ASAL counties like Laikipia

There are 30,000 known edible plant species while today we only grow about 170 crops on a commercial scale globally[54]. There is an immense opportunity to document and re-discover 'forgotten' indigenous foods of the ASALs and develop these value chains commercially. It will be important to integrate technologies to support the development of commercial value chains of crops naturally adapted to ASAL climate. It should be noted that enabling small-scale decentralised groups to develop value-added products derived from indigenous plants, native to ASALs, will require a mix of solar powered and mechanical machines. This is illustrated using the examples of opuntia cactus and honey production below.

1. Use of machinery in the opuntia (prickly pear cactus) value chain

   Opuntia cactus is listed among the 100 worst global invasive alien species by The World Conservation Union (IUCN)[55]. According to some evidence, it has spread over 50 – 75% of communal grazing fields. Broken chunks of this species can resprout into new plants. Presence of spines and glochids causes injuries to both humans and animals. Livestock that may feed on it can get injured in their eyes and mouths. Its indigestible seeds can clog animal intestines[56].

   Opuntia emits high amounts of methane gas upon decomposition. LPC is testing this plant for 3 commercial uses, all of which require use of mechanical and solar equipment for processing, see Figure 20.

   - As fuel for biogas: Italian based NGO, Ipsia, is working with LPC to determine the feasibility of substituting cow dung with opuntia as fuel for making biogas.
   - Extraction of oil from seeds of opuntia flowers for medicinal and cosmetic applications.
   - Extracting fruit pulp for making jams and juice.

[54] Food and Agriculture Organisation of the United Nations, Once neglected, these traditional crops are our new rising stars, how overlooked and underutilized crops are getting their turn in the the spotlight (Food and Agriculture Organization of the United Nations, 2021), https://www.fao.org/fao-stories/article/en/c/1154584/

[55] Lowe, S., Browne, M., Boudjelas, S., De Poorter, M., 100 of the World's Worst Invasive Alien Species A selection from the Global Invasive Species Database, (The Invasive Species Specialist Group, 2000), https://portals.iucn.org/library/sites/library/files/documents/2000-126.pdf

[56] IMPACT Kenya, Opuntia Stricta Invasion (IMPACT, 20221), https://www.impactkenya.org/post/opuntia-stricta-invasion

Image 20A: Patches of opuntia growing invasively across Laikipia communal grasslands

20B: Opuntia fruit, fruit seeds and oil extracted from seeds

Image 20C: Machine for crushing opuntia pads for bio-gas

Image 20D: Biogas flex tube trialling use of opuntia pads mixed with cow dung for biogas generation

Image 20E: Machine for pulping fruit

Image 20F: Cold pressed oil extractor imported from Germany

Figure 20: Opportunities for commercialising an invasive species like opuntia

2. Use of machinery in honey production

While the role of electric appliances in small-scale honey production may be limited, there is a need for mechanical appliances. Honey production can help boost and diversify incomes while providing indirect benefits by boosting farmer resiliency and de-risking solar payments.

Hives can yield honey 2-3 times a year in flower blooming seasons between March - May, August – September and October - December.

Image 21A: Centrifugal machine

Image 21B: Honey press

Figure 21: Examples of machines for small scale mechanical honey production

3. Note on oil extractors

Issues such as post-COVID-19 supply chain disruptions, currency fluctuations, the war in Ukraine and ban on palm oil exports by Indonesia has hampered the importation of raw materials used in production of cooking oil, leading to inflationary pressure[57]. As part of resilience measures, local production of healthy cooking oil should be promoted. Sunflower oil could be cheapest to produce because it can be grown anywhere including dry areas. Sunflowers are also particularly suitable to a regenerative approach as they are great for pollination, shade and companion planting, and meal left over after oil extraction can be fed to chickens. Cold-press oil extraction could be a key technology for use in ASAL regions as several indigenous species can yield oil for medicinal use. These include oils such as that of prickly pear, moringa, vetiver and several others. Some of these already have a big market in the health, beauty and lifestyle segment[58].

[57] Wakarima, Leah., Cooking Oil Prices Set to Rise Further Over Looming Dollar Shortage, (Kenyan Wall Street, 2022), https://kenyanwallstreet.com/cooking-oil-prices-set-to-rise-further/

[58] Import Promotion Desk, Pricky Pear Seed Oil, Treasure from the Desert, (German Federal Ministry for Economic Cooperation and Development: Import Promotion Desk, accessed April 2023), https://www.importpromotiondesk.de/fileadmin/Importeure_Brancheninformation/NI/210617_IPFS_Prickly_pear_seed_oil_final.pdf

Case study 5: Horticulture crop value chain, Murange and Kiambu

General notes on vegetable production in Kenya

Vegetable production in Kenya is undertaken by both smallholder farmers and by large-scale commercial horticulture initiatives. Vegetable production requires large amounts of water for irrigation. For this reason, vegetable production by small-scale farmers, who often do not have access to water pumps, is carried out in areas of water surplus and/or during rainy seasons. Commercial horticulture production which employs large-scale irrigation is less reliant on seasonal rainfall and therefore is carried out across drier regions of counties such as Laikipia[59] where both sunny weather and water from Mt. Kenya is available downstream for lowland users. The commercial horticulture sector is Kenya's second largest foreign exchange earner[60]. While most of the commercially produced vegetables are exported, Kenya's domestic vegetable consumption is among the lowest in the world. Production levels by smallholder farmers are also low and irregular due to insufficient irrigation, a lack of quality seeds, degraded soils, pests and diseases. Regenerative farming practices for horticulture production among small-holder farmers can help boost vegetable yields and increase the availability and affordability of vegetables for the domestic market.

Introduction to organisation(s)/initiative(s)

World Vegetable Center and SNV are implementing an initiative called the Veggies for Planet and People (V4P&P) that aims to pilot and scale regenerative vegetable production, with funding from IKEA Foundation[61]. This case study includes findings from farmers working with WorldVeg and SNV in Muranga county.

In Muranga county, farmers typically lease on average 0.125 - 0.5 acres of land for vegetable production. In addition, farmers own land at an average land holding size of 1-2 acres. With capacity building support from WorldVeg and SNV, farmers are growing a variety of vegetables including several indigenous leafy greens such as kale, nightshade, spinach and amaranth.

Farmers own land along the slopes, and lease land in the valley below where there is surplus water, making vegetable production suitable. During long rain seasons, March – May, heavy flooding occurs. Farmers have made canals to drain water into the river, but this measure is not sufficient as flooding still occurs and can sometimes destroy crops. When flooding occurs, farmers move their farming up the hills as a coping measure. Rainwater harvesting specialists could advise on how flooding could be converted from a risk into an asset, by collecting and re-directing water into appropriate storage tanks and nearby surface water bodies. Water harvesting measures like this could be combined with solar water pumps to help redistribute water from storage tanks instead of using them for extracting water from rivers or groundwater sources.

Figure 22: Farmers have canals to drain water into the river, but this measure is not sufficient. Flooding still occurs during long rains and destroys crops.

[59] Lanari, Nora., Commercial Horticulture in Kenya: Adapting to Water Scarcity, (Social and Hydrological Information Platform, 2014), http://docrepo.wlrc-ken.org/xmlui/handle/123456789/93

[60] Ibid.

[61] SNV, Veggies for Planet and People, (SNV, 2023), https://snv.org/project/veggies-4-planet-and-people

Farmer experience with regenerative agriculture

The farmers have been implementing regenerative agricultural practices since 2021. Farmers have been trained on the following types of regenerative farming practices:

- Use of compost and manure
- Crop rotation
- Mulching
- Use of bio- pesticides e.g. titonia tea, neem, cow urine
- Integration of grasses, sunken beds, canals
- There is a plan to ingrate trees with vegetable crops (agroforestry)

Farmer observations on soil and plant health after a year of following regenerative practices include:

- Improvement in soil fertility
- Longer harvesting cycles – consistent harvest for longer period of time
- Lower instances of pests, leading to a reduction in input costs on pesticides
- Improvement in vegetable yields by 10% boosting farmer income

Fertilizer economics – savings in input costs

Reduction in reliance on synthetic inputs can make a regenerative farmer more resilient

Based on the data provided by farmers, fertilizer costs have almost doubled for farmers who are continuing to use the same level of synthetic fertilizers as before. This is partly because of the recent (since 2020) fertilizer price increase driven by geopolitical tensions and supply chain issues. Increase in prices of synthetic fertilizers is helping strengthen the case for regenerative agriculture from a farmer economics point of view as explained before, see sub-section 'Fertilizer economics' under Case Study 1 for coffee value chain. Furthermore, due to lower levels of pest attacks after following regenerative farming practices, farmer pesticide use has reduced by 50% compared to the previous input requirements. Vegetable yields have also improved by 10%, boosting farmer income further. Such savings in input costs, greater income and resiliency levels of smallholder regenerative farmers also help boost the bankability of farmers for selling solar technology assets on market-based principles. See sub-section 'Why is it important to have this conversation?'

Role of solar technologies in the traditional vegetables value chain

1. Pumps: According to the farmers, hot and dry conditions are better for growing vegetables, as fungal diseases tend to thrive in cooler climates. However, a lack of water access/artificial irrigation is the limiting factor for smallholder farmers to carry out vegetable production in such climates. Most vegetable production occurs during the rainy season, when supply is high and demand is low. During the rainy season most farmers undertake vegetable production, kitchen garden or otherwise. During the dry season, only people who have access to irrigation can produce vegetables. Therefore, access to pumps is key to enable vegetable farmers to produce during the dry - season and realise better revenues. Integration of pumps should be done alongside implementing rainwater harvesting strategies. Given that counties such as Muranga and Kiambu receive adequate levels of precipitation, the bulk of their irrigation demand could be met from use of appropriate rainwater harvesting strategies that catch rainfall across farmer fields. This will allow for use of pumps to primarily distribute collected and stored rainwater, using rivers and groundwater sources for back-up needs. It is important to integrate filtration technology in drip lines for crop

production in lowlands as surface run off water carries a lot of dust and mud.

2. Cold storage: For horticulture production, perishability rate is high. Leafy greens and flowers tend to wilt and their quality starts to reduce in a few hours without access to cold storage. Moreover, aggregation across several small holder farmers is a requirement for economic viability of expensive cold storage technologies. WorldVeg and SNV are working with the Kenyan Ministry of Agriculture to pilot aggregation centres that will be run by the community.

3. Agricultural processing equipment such as solar dryers and vegetable crushers: Farmers have poor negotiating power with brokers. WorldVeg and SNV plan to develop a farmers' planting calendar that focuses on growing produce during the off-season when vegetable supply is low, and prices are high. While a farmers' calendar will help, creating value-added products such as dehydrated vegetables, powdered greens, pre-prepared ready-to-cook vegetables etc. by mentoring entrepreneurs could significantly help reduce post-harvest losses by utilizing all unsold produce, something that WorldVeg and SNV are exploring with partners like NatureLock. Solar dryers can be a powerful aide alongside cold storage in reducing food losses and significantly increasing food shelf life to deliver impacts such as food security and enhanced nutrition. Farmers could use solar dryers and vegetable crushers to make powders out of greens such as nightshade, swiss chard and amaranth for flour to package and sell or use for self-consumption. In terms of size, both portable and large-scale units are needed to help with community-based decentralized models, where dryers could be taken from farm to farm, and also to centralise large-scale production.

4. Chaff cutters for scaled production of compost, as discussed in case study 1, coffee value chain.

5. Efficient cookstoves: As noted in case study 1, coffee value chain, while efficient cookstoves are not a productive use energy technology, their integration from an energy point of view is key to maximise positive impacts from with regenerative practices like agro-forestry, biomass for mulch and composting.

In summary, the following 8-point agenda is proposed for the consideration of energy practitioners while determining appliance suitability for integration in regenerative farming systems.

1. A crop value chain led approach

There is a need to study different crop value chains separately while proposing appliance categories that would be most suitable to the crop in question as opposed to working from a technology led lens that considers the crop value chain second.

Contextualising appliance integration across key criteria such as agro-ecology, types of crops that can be mixed with the main cash crop, water demand, soil type, rainfall, farmland size etc. within a specific value chain can help inform key technology specifications within an appliance type and the aspects of the appliance business model within which appliance access would be most successful.

2. An interdisciplinary approach involving regenerative agricultural specialists

Enabling clean energy access in the past has been driven by teams specialising in socio-economic and technology-led disciplines. Due to the applied orientation of agriculture, especially regenerative agriculture which is still a somewhat fringe and not mainstream discipline, it is important to involve and consult regenerative agricultural specialists.

Farmers operate in a wide variety of socio-economic and agro-ecological contexts which are becoming more complex due to increasing climate variability. Improved understanding of farmer decision-making can only be facilitated by combining different forms of knowledge which will in turn provide answers to the question of 'how best small-holder farmers undertaking regenerative agricultural practices can benefit from off-grid solar appliance categories'. For instance, excessive soil tillage can degrade soil structure and use of heavy farm machinery can lead to soil compaction, disrupting fungal networks. It is necessary to involve regenerative agricultural experts in solarisation efforts to inform technology suitability and its integration in the least harmful manner.

3. An inter-disciplinary approach involving water harvesting specialists

When designing interventions related to enabling access to artificial irrigation via solar water pumps, it is important to involve water harvesting specialists and build in costs for site assessment to recommend appropriate irrigation solutions.

In the face of increasing drought risk and flooding events, the first interventions should aim to build moisture retention capacity in the soil and reduce evaporation. Regenerative farming aspects such as mulching, substituting synthetic inputs with bio-inputs and crop diversification help improve soil health and therefore, will play a natural role here. Furthermore, grey water recycling and utilising earthwork structures for water harvesting and storing rainwater will be key. These techniques could drastically bring down demand for irrigation. Pumps can then be used to redistribute stored rainwater for irrigation, extracting water from surface water bodies or the ground only when required for backup, when the stored rainwater supply is exhausted. This will have a 3-fold benefit:

1. Significantly reducing the risk of drying up of shallow wells and over extraction of groundwater;

2. Re-channelling excess rain water outside the fields, reducing the risk of flooding;

3. Potential reduction in the size of the solar pump needed, in turn helping to reduce affordability issues related to pump installations. Sustainable water management using traditional systems such as zai pits (as discussed in the maize case study), does not fall within the purview and therefore the skillset of a technology-led intervention. Therefore, it is vital to involve water harvesting specialists and include e water conservation efforts when introducing pumping

technologies to ensure long term and sustainable harvesting of river and groundwater supplies.

In conclusion, the cost of site assessments for proposing appropriate water harvesting and water storage measures, suitable pump size, other water and energy efficiency measures such as gravity-based water distribution, sprinkler or drip water farming systems must be included in the cost of enabling access to irrigation.

4. The role of renewables in building an ecosystem for regenerative agriculture

Renewables and machinery are required to scale production of natural fertilizers such as biochar, vermicompost and others.

An ecosystem for inputs that support regenerative practices needs to be built and provided to farmers. Inputs like bio-pesticides and compost/manure may need to be provided at a subsidised rate during the transition phase from conventional to regenerative practices. A ready-to-use bio-inputs value chain at reasonable prices would provide an incentive for farmers to not resort to chemical inputs during the transition. This would require appropriate partnerships between energy access and regenerative agriculture stakeholders.

5. Integrate improved cookstoves and/or other renewable energy based cooking solutions like biogas

While efficient cookstoves or biogas solutions may not be a productive use energy technology in all contexts, their integration from an energy point of view is key to maximise positive impacts from regenerative practices like agro-forestry, biomass for mulch and composting.

In African countries, especially in rural areas, food is predominantly prepared using firewood in traditional cookstoves located within household premises. Excessive firewood consumption and charcoal production for sale for urban use contributes to deforestation and consumption of biomass within farmland.

6. Solar dryers as an important technology

If farmers with fruit trees on their farmland had access to solar dryers, they could dry fruit for self-consumption instead of throwing away fruit during glut season. Cold storage solutions will not be able to completely eliminate food waste and drying technologies can serve as an important complementary solution that can also help with farmer nutritional security.

Any intervention aimed at enhancing uptake of drying technologies for self-consumption of fruit needs to be combined with an intervention aimed at raising awareness on nutrition and importance of diet diversity. Farmers can be capacity built to build do-it-yourself solutions of small-scale solar dryers.

7. Bearing risk during the period of transition from conventional to regenerative farming

While increases in synthetic fertilizer prices have helped strengthen the economics for using natural fertilizers, additional support may be required as the farmer transitions from conventional farming methods to regenerative farming. Energy access practitioners would need to take this into account while developing end-user financing plans for solar technologies.

Smallholder farmers need a third-party risk bearing mechanism during the transition phase from conventional to regenerative practices. This is especially true in contexts where farmers have been using a high degree of chemical inputs and there is a risk for drop in yields in the initial years as farmers phase out use of chemical inputs and allow soil health to build naturally. Premium prices for organic produce can help by acting as a financial incentive where possible, and market linkage support would need to be provided.

8. Hub model approaches

Energy access practitioners in partnerships with regenerative farming programmes can develop community-run aggregation centres that serve as *hubs for providing both agricultural inputs and energy services.*

Farmer groups whether agricultural societies, cooperatives or any other mechanism) help to provide meaningful aggregation and appropriate market linkages. Provision of solar technologies that require a certain level of aggregation across farmer groups for reasons including economic viability, inventory management constraints, logistical reasons, could piggyback on existing infrastructure for provision of agricultural inputs. A central location such as the premises of the local society, cooperative or other agricultural support organisations such as the offices of the agricultural extension service officers, could be used to provide access to solar technologies based on servitisation models. Servitisation models help ease logistics issues typically associated with keeping repair processes affordable and can help bring down solar appliance downtime and maintenance costs per user. There could be further benefits such as time-use efficiencies by avoiding the need for farmers to have to travel to multiple locations to access different services.

As a next step, it would be important to build on this work by i) employing the 8-points of consideration highlighted above; ii) piloting the technologies identified in the case studies covered in this report; and iii) documenting the impact of energising regenerative agricultural efforts.

efficiencyforaccess.org
info@efficiencyforaccess.org
@EforA_Coalition