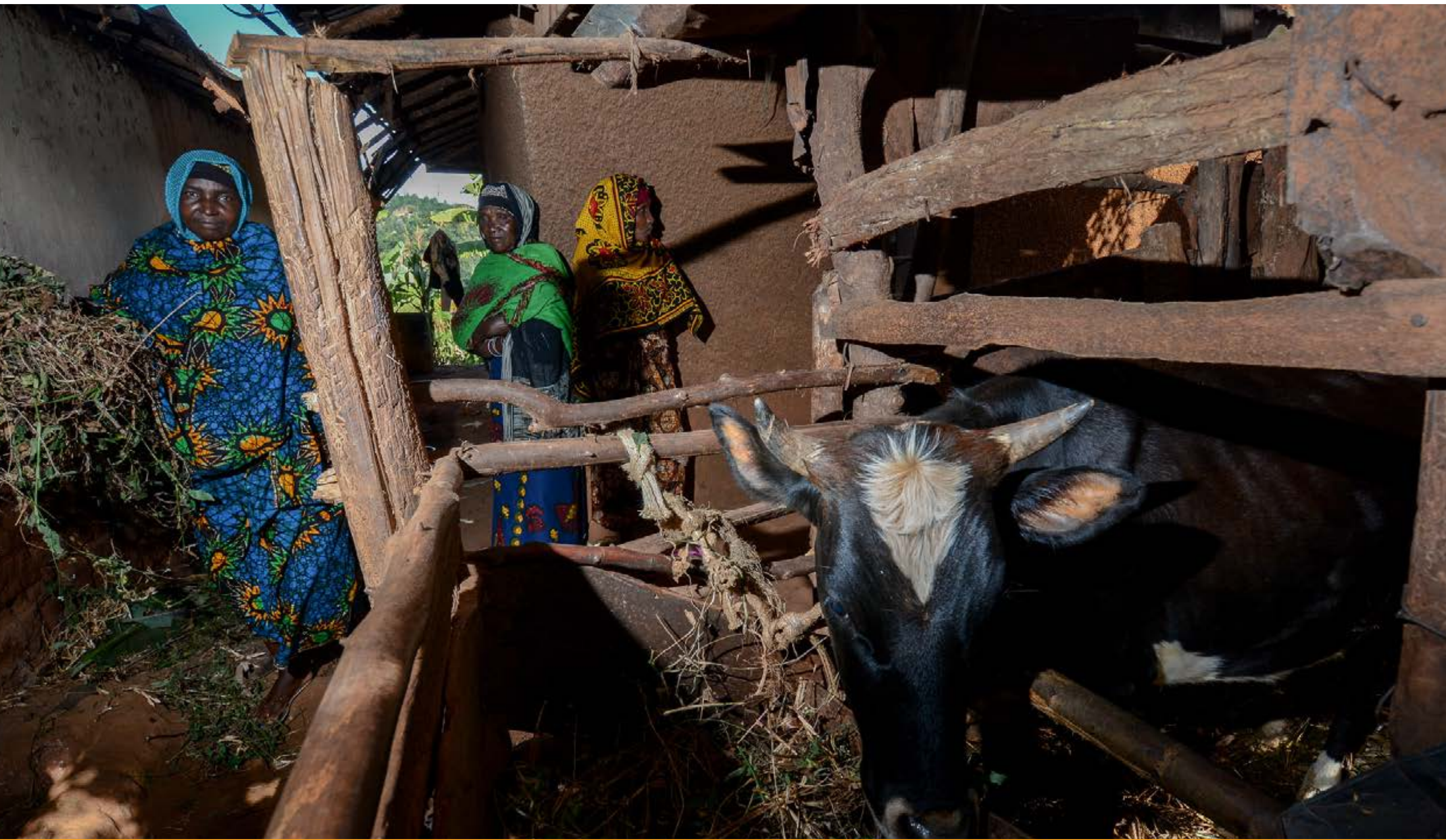
More meat milk and eggs by and for the poor



Environmental Management in Smallholder Dairy Production in Tanzania

A Training Manual for Agripreneurs and Technical Extension Staff

David Ngunga[1], Beatus Nzogela[1], Jonas Kizima[2], Walter Mangesho[2], David Maleko[3] and Birthe Paul[1]

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Version I (September 2021)

Cover Image: Local livestock feed does not have the same nutritional value as improved varieties. Livestock farmers in Tanzania, are finding ways of boosting their production and lowering their environmental impact by planting improved forages. (Credit: GeorginaSmith /CIAT)

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Citation:

Ngunga, D., Nzogela, B., Kizima, J., Mangesho, W., Maleko, D., Paul, B. (2021). Environmental Management in Smallholder Dairy Production in Tanzania – A Training Manual for Agripreneurs and Technical Extension Staff. Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) Nairobi, Kenya.

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Local livestock feed does not have the same nutritional value as improved varieties. Livestock farmers in Tanzania, are finding ways of boosting their production and lowering their environmental impact by planting improved forages. Credit: GeorginaSmith/CIAT

Acknowledgements

The authors would like to express sincere thanks to SNV Netherlands Development Organisation Tanzania and Solidaridad Tanga for their close collaboration and technical support in the development of this training manual. We would also like to thank Mkinga, Muheza, Hai, and Siha Districts for collaboration and coordination in the implementation of the study that formed a basis for this training manual. Thanks also to all the participants in the stakeholder workshop in December 2020 in Arusha (https://hdl.handle.net/10568/111298) that provided key input. This work was supported by the Environment Flagship of the CGIAR Research Program on Livestock, which is supported by contributors to the CGIAR Trust Fund (http://www.cgiar.org/about-us/our-funders).

Dairy cows feeding on well-constructed feed trough in Daluni village in Mkinga Tanga Region. Credit: David Ngunga/Alliance

List of acronyms

Alliance	The Alliance of Bioversity International and CIAT
CO2eq	Carbon dioxide equivalent
CH_4	Methane
CIAT	International Center for Tropical Agriculture
FAO	Food and Agriculture Organization of the United Nations
FPCM	Fat and protein corrected milk
GHG	Greenhouse gas
N_2O	Nitrous oxide
NDF	Neutral detergent fibre
NH_3	Free ammonia
NH_4^+	Ammonium
t	Tonnes

1. Introduction

The dairy industry is one of the most important agricultural subsectors in Tanzania. It is perceived by numerous farmers as an important activity and plays a major role in the economic and social lives of many households by contributing nutritious foods, jobs and employment, assets and savings, soil fertility, and income generation (FAO & New Zealand Agricultural Greenhouse Gas Research Centre, 2019). The national dairy cattle herd includes the traditional sector that contributes 70% of the total milk produced, while the remaining amount comes from smallholder dairy farmers with crossbred and purebred Bos Taurus cows (Njombe et al., 2011).

The development of the dairy sector is supported by outstanding natural resources such as extensive rangelands and diverse natural vegetation that supports cattle feeding. Two thirds of the country's 88.6 million hectares are suitable for grazing. Despite these resources, the sector performs below its potential. The dairy industry has seen an increase in livestock numbers of 4.3% but only a small gain of 1.8% in productivity (FAO & New Zealand Agricultural Greenhouse Gas Research Centre, 2019). Smallholder dairy farmers experience unsatisfactory production for several reasons, including a supply of dairy feed that is erratic both in quality and quantity, the presence of low-yield breeds, and a lack of appropriate management practices (Mbwambo et al., 2017). Despite undergoing enormous growth, dairy farming in Tanzania has been facing significant challenges in accessing fodder of sufficient quantities and quality, especially during the long dry season, to facilitate the sustainable production of milk and meat; as a result, animals are fed on undesirable feedstuffs, which can lead to lower milk production and animal productivity (Maleko et al., 2018).

The population of both humans and livestock is increasing in Tanzania, while the size of the land area remains constant, implying that open grazing lands are dwindling. In addition, there has been a trend toward rapid evolution of property rights from large parcels of land under village or communal ownership to small parcels of land under private ownership. Climate change and unpredictability exacerbate the situation by lengthening dry seasons and increasing the frequency of severe droughts, resulting in water and pasture scarcity. Despite these problems, the country's need for milk and meat is rising as the population expands. It remains uncertain how we can produce meat and milk for the purposes of creating income and guaranteeing food security for the rural poor without harming or polluting our environment.

This training manual was developed to guide the training of trainers such as agripreneurs, technical extension staff, and lead dairy farmers in acquiring the necessary information and practical skills for environmentally sustainable dairy production in Tanzania. It builds on this review of existing training materials, as well as outputs from a stakeholder workshop in December 2020 in Arusha.

2. Dairy production and environmental impacts

Regardless of the sector's potential contribution to the health, nutrition, and income generation of smallholder producers in Tanzania, dairy production is seen as one of the major contributors to environmental degradation.

2.1 Land degradation and loss of vegetation cover

Continuous grazing or overgrazing, as well as the cut and carry of plant biomass to feed animals without replenishing nutrients, have been identified as a major environmental issue in Tanzania. Soil erosion and land degradation have been blamed on the mismanagement of grazing animals.

2.2 Greenhouse gas emissions and climate change

The dairy subsector in Tanzania is estimated to emit about 28.8 million tonnes of carbon dioxide equivalent (t CO2eq) annually. Methane from enteric fermentation accounts for 91.4% of the total greenhouse gas (GHG) emissions for dairy production in the environment. Emissions associated with the management of stored manure such as methane (CH_4) and nitrous oxide (N_2O) represent a further contribution of 2.3 million t CO2eq or 8.2% of the total GHG emissions from the dairy cattle sector (FAO & New Zealand Agricultural Greenhouse Gas Research Centre, 2019). Traditional livestock systems are responsible for the bulk of the emissions—97%—while improved dairy systems only contribute 3% of the total emissions. At the national level, the emission intensity of milk produced in Tanzania is on average 19.9 kg of CO2eq per kg of fat and protein corrected milk (FPCM). Traditional systems produce emissions ranging from 20.3 to 28.8 kg CO2eq/kg FPCM, whereas upgraded systems produce emissions ranging from 1.9 to 2.2 kg CO2eq/kg FPCM. In both systems, emissions intensity was lowest in the temperate highlands and highest in the semi-arid zones (FAO & New Zealand Agricultural Greenhouse Gas Research Centre, 2019). Thus, the majority of emissions from on-farm dairy production arises from enteric fermentation, manure deposition by grazing animals, manure management, and the application of manure to agricultural land. Providing dairy animals with poor-quality feeds results in low productivity and digestibility of feed and, as a result, in high emission intensities.

2.3 Water use and pollution

Improper animal manure storage and management procedures can cause environmental problems. Animal waste runoff, known as slurry, which contains the soluble nutrients in manure, may end up in drainage channels, ditches, and eventually flowing rivers (Figure 1). The nitrogen, phosphorus, and potassium content of the manure causes hypertrophication and leads to masses of algae (Nonga, 2011). These algae blooms can completely block all available light from the water and obstruct the breakdown of organic matter, resulting in a high biological oxygen demand and oxygen depletion. These processes in turn are detrimental to living organisms such as fishes and aquatic plants in the area. Also, animal wastes mean additional suspended material in the water solution and, together with the decomposition of organic matter, can cause the water body to have a strong, unpleasant odour, taste, and colour. Furthermore, dairy production is known for its intensive use of drinking water, which is a challenge for resource-constrained areas.

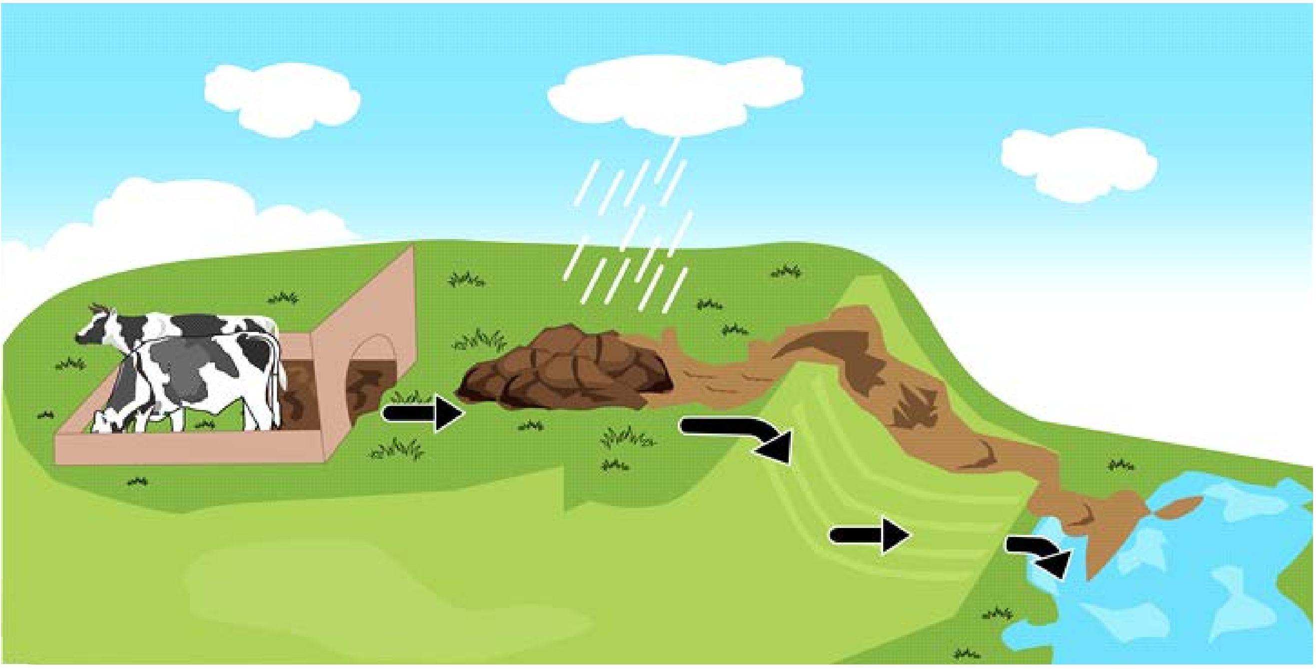

Figure 1: *Uncovered cattle manure draining its slurry into a surface water resource.*

3. Environmentally friendly practices for dairy farmers

The following five main training topics have been recognized as key practical interventions that are recommended for delivering environmental improvements in Tanzania's dairy sector:

i. Sustainable soil management practices.

ii. Improved animal feeds, feeding management, and nutrition.

iii. Higher animal production through genetics and other management approaches, including better nutrient utilization for productive purposes to reduce maintenance on an individual animal or on a herd basis, increased feed efficiency, and decreased CH_4 per unit of meat or milk products.

iv. Enhanced animal health and infrastructure.

v. Proper manure management and use of biogas.

Better environmental management practices, integrated into smallholder dairy keeping, can lessen adverse impacts on the environment. Opportunities for improved environmental management can be actualized across various areas in the country.

3.1 Sustainable soil management practices

Intensive dairy production can lead to soil and water pollution. Inappropriate use and management of organic and inorganic fertilizers and of water, as well as improper manure disposal, all lead to high concentrations of nitrogen, phosphorus, and animal waste (Nonga, 2011; Kusiluka et al., 2012). Appropriate technologies—including soil and water conservation, soil fertility management, agroforestry, water harvesting, conservation agriculture, and indigenous knowledge—can augment productivity and production (Majule & Shishira, 2008). Examples of the technologies involved in enhancing soil management include the following (Figure 2).

Figure 2: *The upper image depicts a heavily grazed area with many animals, experiencing wind and water erosion due to a loss of vegetation cover. The lower image shows an area with fewer animals and vegetation cover, as well as healthier cows with increased milk production.*

Soil erosion control: Soil erosion is caused by wind, water, or deep tillage, and leads to deterioration of the physical, chemical, and biological properties of soils and to the loss of natural vegetation. Recommended practices to control erosion include the use of farmyard manure, agroforestry, improved fallow, mixed farming, minimum land tillage, and growing forage grasses especially on contours.

Vegetation management: Improper cultivation practices, deforestation, overgrazing, fires, and collection of wood for fuel and construction are the major causes of vegetation degradation in this region. The natural regeneration of plants can be promoted through destocking, confining dairy animals, and restricting shifting agriculture and tree planting.

3.2 Improved animal feeds, feeding management, and nutrition

It is well known that feed contributes about 60-70% of the costs in dairy production. Roughages including forage grasses, legumes, and crop residues are the key feeds for ruminant livestock, including dairy cattle and goats. Local production of roughages, and in particular, on-farm production of forage grasses and legumes, is not only profitable but also conserves the environment and provides households with multiple benefits.

Dairy animal performance can be optimized through high-quality forages, which can tremendously improve milk production, animal growth, conception, and calving, while also reducing disease risks (Figures 3 and 4). Furthermore, high-quality forages, such as Brachiaria grasses, contain less fermentable fiber and pass through the digestive tract faster, allowing cows to consume more feed and produce more milk. The less time spent in enteric fermentation, the less CH_4 is generated. High-quality diets can increase net energy intake, and if the net energy is partitioned to milk, it will reduce CH_4 production. Establishment of multi-purpose trees such as *Leucaena* can serve as protein sources in animals' diets as well as contributing to climate change mitigation.

Figure 3: *Dairy cows feeding on corn silage in Kilimanjaro Region. Credit: David Ngunga/Alliance*

Figure 4: *Improved forage species Brachiaria hybrid cv. Cobra in Tanga. Credit: David Ngunga/Alliance*

3.3 Forage conservation

Forage quality can be enhanced by harvesting or grazing less-mature forages, selecting strains or species with strong genetic potential, growing improved forages that have superior digestibility such as Brachiaria grasses, and storing forages properly, especially ensiling into hay, silage, or leaf meal, to conserve digestible nutrient content, improve dietary utilization, and increase feed efficiency (Figures 5 and 6). In general, better-quality forages will contain a greater proportion of non-structural carbohydrates to neutral detergent fibre (NDF), or the NDF will be less woody to enable fast digestion and passage through the digestive tract.

Figure 5: *Integrated improved forage, namely Brachiaria grass, and vegetable production for greater availability of dairy feed and soil improvement. Credit: David Ngunga/Alliance*

3.4 Feed processing

Processing forages by chopping them into the recommended size of 5-10 cm or by pelleting them will increase rumen NDF digestibility and can lessen CH_4 emissions as result of an increased passage rate.

Figure 6: *Improved forage (Brachiaria cv. Cobra) preserved in the form of silage and hay in Siha District, Kilimanjaro Region, and Muheza District, Tanga Region. Credit: David Ngunga/Alliance*

3.5 Improved animal genetics

About 97% of the cattle population in Tanzania is comprised of local breeds. While they are adapted to feed and water shortages, disease challenges, and harsh climates, the productivity of these breeds is generally suboptimal. Milk production is as low as 5 to 8 liters per cow per day over a lactation period of 200 days. Enhancing the genetic potential of dairy animals is critical, but it is equally important not to promote animals with strong genetic potential into climates and management environments where they cannot achieve their promise and will, in fact, perform worse than native breeds or crossbreeds due to management, disease, or climatic challenges. Herds of cattle are large in many sub-Saharan countries because the animals fulfill multiple roles ranging from draught power to the production of manure, milk, and meat, with low levels of nutrition supply that diminish production. This situation creates high competition with other users of land and water resources and the environment.

An acceptable, efficient, and sustainable method of production, such as genetic selection and breeding, could enable environmental sustainability in the dairy production system (Figures 7 and 8). Genetic selection can increase the productivity of animals. Breeding can help adapt animals to local conditions and address issues associated with reproduction, vulnerability to stress, adaptability to climate change, and disease incidence. Better breeding management practices, such as using artificial insemination and ensuring access to wide genetic pools for selection, can accelerate those gains (FAO, 2014).

Figure 7: *Improved dairy cows in Daluni Mkinga District, Tanga Region, feeding on improved forages (Brachiaria cv. Cobra) to enhance milk output while lowering greenhouse gas emissions. Credit: David Ngunga/Alliance*

3.6 Improved animal health and infrastructure

Improving animal health services, including disease prevention and management, has notable benefits for the efficiency of livestock systems and food security, while reducing GHG emissions. Dairy cow performance is affected by the occurrence of numerous animal illnesses, tick-borne infections, and internal and external parasites. The "unproductive emissions" connected to death and sickness impact the emission intensity of animals. Animal death rates are substantial, ranging between 15% and 25% for calves. Many health problems originate because animals are in poor condition due to inadequate nutrition, but also due to the limited availability of animal health care. Sickness has an indirect effect on emission intensities because it causes slower growth, lower mature weight, worse reproductive performance, and a diminished milk supply (Kusiluka et al., 2012). The major animal pests and diseases in the tropics are East Coast Fever, contagious bovine pleuropneumonia, brucellosis, rinderpest, ticks, and internal parasites.

Improving reproduction rates and extending the reproductive life of animals will increase productivity and lower CH_4 and emission intensities. Relevant interventions include reducing the incidence of endemic, production-limiting diseases that have several negative outcomes, including death or cull of previously healthy animals, decreased live-weight gain, suboptimal milk yield and quality, lessened fertility, abortions, and additional waste. Healthier animals are generally more productive and have lower CH_4 emission intensities.

3.7 Manure management practices

In most small-scale livestock production systems in Tanzania, proper integrated manure management is not practiced, resulting in nutrient loss, environmental degradation, human and cattle health hazards, and GHG emissions (Figure 9). The difficulties in management could be due to a lack of either an ideal location to dispose of cow manure or appropriate technology to reuse it and comply with environmental rules.

Diet can have a significant impact on the chemistry of manure, including faeces and urine, and, as a result, on GHG emissions during storage and after application. Organic nitrogen and inorganic ammoniacal nitrogen are both present in animal manures. The majority of organic nitrogen is found in organic matter, whereas ammoniacal nitrogen is found in the form of ammonium (NH_4^+) or free ammonia (NH_3). When NH_4^+ is exposed to the open air, it degrades into gaseous NH_3, which is then released into the atmosphere (FAO & New Zealand Agricultural Greenhouse Gas Research Centre, 2019). Reduced dietary nutrient digestibility is likely to heighten the fermentable organic matter concentration in manure, thereby increasing CH_4 emissions. As an effective emission mitigation strategy for ammonia and N_2O in manure, feeding protein close to an animal's requirements, including altering dietary protein concentrations with lactation or according to growth stage, is recommended. Low-protein diets for ruminants should be balanced for rumen-degradable protein so that microbial protein synthesis and fiber degradability are not impaired (CIAT & World Bank, 2017).

The use of semi-permeable covers is valuable for reducing ammonia, CH_4, and odor emissions at storage, but is likely to increase N_2O emissions when effluents are spread on pasture or crops. Impermeable membranes, such as oil layers and sealed plastic covers, are effective in reducing gaseous emissions but are not very practical. Combusting accumulated CH_4 to produce electricity or heat is recommended. Further effective methods for reducing ammonia and CH_4 emissions from stored manure include cooling and, in areas where soil acidity is not an issue, acidification. Composting can effectively reduce CH_4 but can have a variable effect on N_2O emissions and increases ammonia and total nitrogen losses. Anaerobic digesters are a recommended mitigation strategy for CH_4 that generate renewable energy and provide sanitation opportunities in developing economies, but their effect on N_2O emissions is unclear (Mushi et al., 2015). Management of digestion systems is important to prevent them from becoming net emitters of GHGs (Figure 10; FAO, 2010).

Figure 8: *A heap of uncovered manure, leading to emissions of methane and nitrous oxide gases and considerable nutrient losses. Credit: David Ngunga/Alliance*

Figure 9: *A heap of covered manure on a small dairy farm. Credit: David Ngunga/Alliance*

Figure 10: A structure designed to for storing cattle manure; the manure is stacked in four phases, with 21 days in the first three phases and 14 days in the fourth phase, until it comes to maturity and can be applied on the farm. Credit: David Ngunga/Alliance

3.8 Use of biogas

Organic waste can be collected and used to make biogas, a renewable source of energy, to minimize GHG emissions and the dangers of pollution to rivers. When biogas replaces fossil fuels, it decreases emissions even more, resulting in carbon-negative systems in some cases.

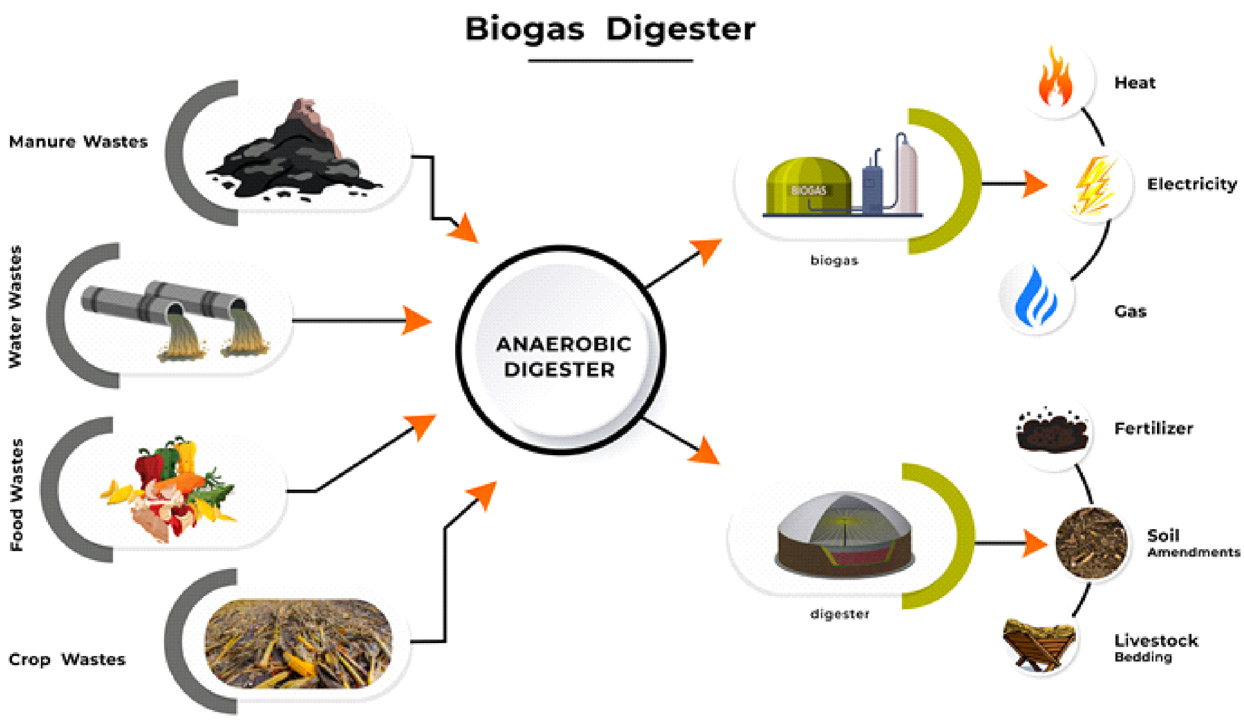

Figure 11: Overview of the manure chain from collection to application

Biogas provides a clean and easily controlled source of renewable energy and, when adequately applied, can significantly reduce observed rates of deforestation (Figure 11). Biogas has dual potential applications. It can be used directly to replace firewood and charcoal and hence slow the rate of deforestation. Alternatively, it can be converted to electricity using a heat engine, which can solve electric energy challenges. Biogas can also lessen emissions in the air and soil. Slurry from manure stored in biodigesters for biogas emits less N_2O than fresh manure applied directly to grassland (Amon et al., 2006; Lekule & Sarwatt, 1997). During storage and anaerobic digestion in biodigesters, readily available carbon in slurry, which could cause denitrification, is incorporated into the microbial biomass or is lost as CO_2 or CH_4. As a result, there is less available carbon in the slurry to fuel denitrification when the slurry is applied to land (Mushi et al., 2015). Indeed, controlled anaerobic digestion is potentially a “win-win” management of animal manure, since CH_4 emitted during storage as a biogas is used to produce heat and electricity, while N_2O emissions after digested slurry is spread are also reduced. The rate, timing, and placement of animal effluent applied to soils all affect potential N_2O emissions. Emissions of N_2O from manure are higher when manure is applied to wet soil than when it is applied to drier soil; emission peaks generally occur within 24 hours of application (Mushi et al., 2015; Eckard et al., 2010).

Dairy cows feeding on un-chopped maize stover. Chopping feeds reduce feed wastage. Credit: David Ngunga/Alliance

4. Closing remarks

This training manual cannot possibly cover every local farm situation. However, it gives a good overview of the underlying principles of well-performed, sustainable smallholder dairy production through environmental conservation-based solutions. Although in practice there still are many barriers and bottlenecks hindering the optimal use of sustainable dairy production, applying the best available practices can enhance the production and productivity of livestock, protect nature and the environment, and promote the household economy through dairy business value chains.

Dairy cows feeding on chopped Napier grass. Credit: David Ngunga/Alliance

A dairy cow feeding on Brachiaria Mlato II at Mzee Petro in Hallu Village, Babati Manyara Region. Credit: David Ngunga/Alliance

A dairy cow feeding on dairy meal. Credit: David Ngunga/Alliance

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