Health and socio-economic impacts of methane mitigation farm-scale digesters- Case study Ethiopia

16th of November 2023, Nairobi

Daniel Mulat, PhD
Environmental Researcher
Lab Manager of the Mazingira Centre

https://mazingira.ilri.org/

Challenges - lack of clean cooking fuels

Mitigate+: Research for Low-Emission Food Systems

- **2.3 billion** people worldwide (900 million in sub-Saharan Africa) rely on traditional biomass- lack clean cooking fuels
  - ➢ inefficient and incomplete combustion of traditional biomass is associated with household air pollution (including PM & CO)
  - ➢ **390,000 annual premature deaths in SSA and 4 million** globally (higher than the combined fatality by HIV AIDS, Malaria and TB globally), mostly affecting women and children (IEA…WHO, 2020).
  - ➢ women and children also take the burden of collecting firewood
  - ➢ contributes to deforestation, soil degradation and erosion
  - ➢ contributes to climate change through black carbon emissions and, when the biomass used is harvested unsustainably, through net CO_2 emissions.
- Annual global cost of cooking with dirty fuels is **USD 2.4 T**: USD 1.4 T for health; USD 0.8 T for women's lost of productivity and USD 0.2 T for climate problems (ESMAP, 2020).

- IEA, IRENA, UNSD, World Bank, WHO. 2020. Tracking SDG 7: The Energy Progress Report. World Bank, Washington DC.
- Energy Sector Management Assistance Program (ESMAP). 2020. The State of Access to Modern Energy Cooking Services. Washington, DC: World Bank

Environmental Defense Fund ILRI CGIAR

Challenges- lack of proper sanitation and organic waste management including livestock manure

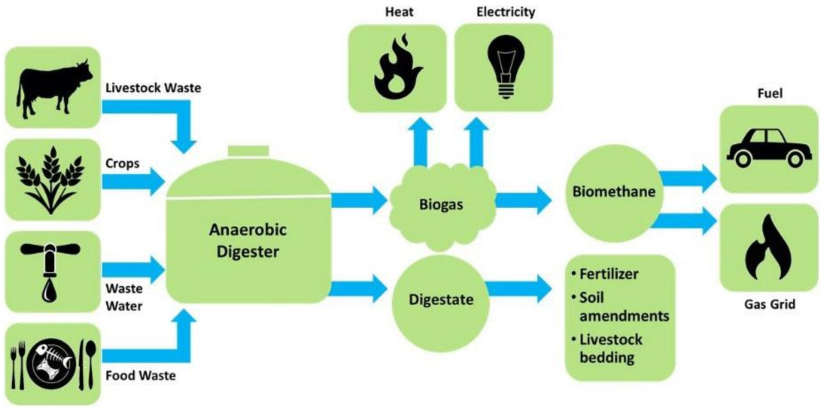
- Sanitation and organic waste management are problems in many sub-Saharan Africa countries
- According to WHO, an estimated 779 million people in Sub-Saharan Africa lack essential sanitation services, including 208 million who still "practice open defecation“
- 125 million tonnes of municipal solid waste (MSW) was generated in Africa in 2012, which is expected to double by 2025 (UNEP)
- More than 90% of waste generated in Africa is **disposed** of at uncontrolled dumpsites and landfills
- On average, 13% of MSW generated in Africa is plastic and **57% is organic waste**
- Organic waste is responsible for 6% of total GHG: 3 times the global emissions from aviation or it would be the world’s third largest emitter.

- https://www.unicef.org/senegal/en/press-releases/africa-drastically-accelerate-progress-water-sanitation-and-hygiene-report
- UNEP: https://wedocs.unep.org/bitstream/handle/20.500.11822/25515/Africa_WMO_Summary.pdf?sequence=1&isAllowed=y

Environmental Defense Fund ILRI CGIAR

Biogas (anaerobic) digesters – circular economy

- Digester treat waste and generate **biogas** and **bioslurry/digestate**
- It creates circular economies –clean energy production and reuse nutrients from waste as fertilizer for growing food and animal feed
- It can potentially address energy, sanitation and waste management challenges
- Digesters contributes to 14 outs of 17 SDGs (directly to six of SDGs)
- If all collectible manure is digested, energy produced meets 100% of the energy needs of global agriculture and offset 930–1260 MT CO_2e emissions/year ~ 13–18% of livestock-related emissions (WBA, 2019)
- Technical potential of livestock manure-fed household biodigesters in developing countries to be over **150 M units** (Asia **100 M**; Africa **32.9 M**; Central and Latin America **20 M)**
- No. of installed digesters: Africa **103,044**; China & India **40 M**; Other Asian nations **1M**

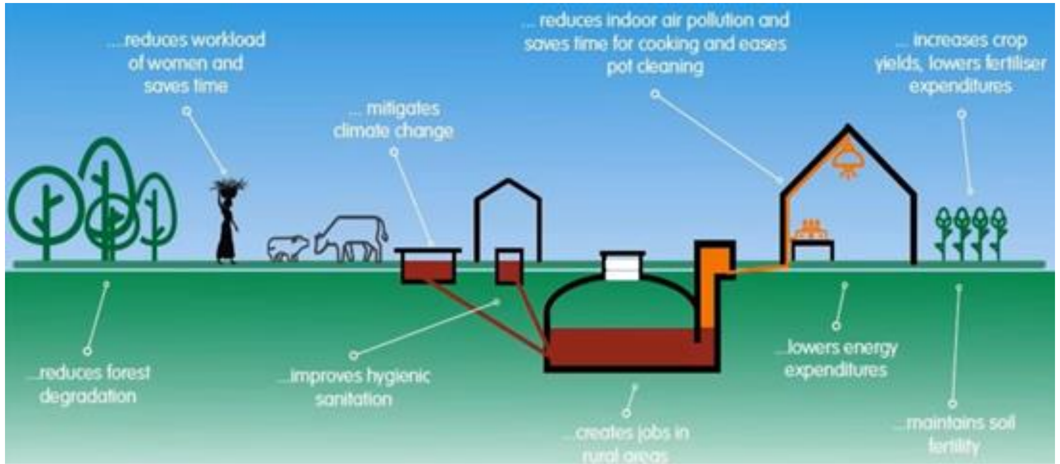


WBA. (2019). Global Potential of Biogas. World Biogas Association. https://www.worldbiogasassociation.org/glo

SNV 2021. Lessons Learnt from the Energy for Agriculture Project

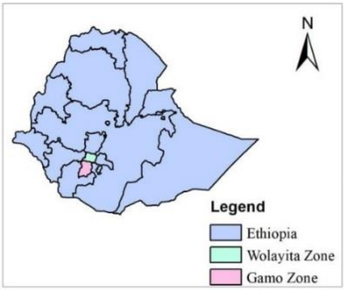
Case Study : Toilet-connected manure fed farm-scale digesters in Ethiopia

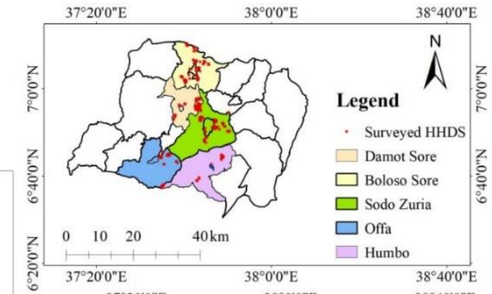
- The digesters are fed with cattle manure and connected to toilet
- This study evaluates biogas digesters effectiveness in in Ethiopia.
  - ➢ Compare indoor air pollution and associated health outcomes (eye and respiratory infections) in households with in the treatment group (biogas user) and control group (biogas non-users)
  - ➢ Compare self-reported prevalence of diarrheal and vectors (flies, mosquitoes and rodents), and occupational health risks (burns and back pain)
  - ➢ Compare the faecal pathogen contamination levels in the manure before and after biogas digestion
  - ➢ Assess the socio-economic benefits of biogas digesters
  - ➢ Understand the overall perception and acceptance of toilet-connected manure fed farm-scale digesters

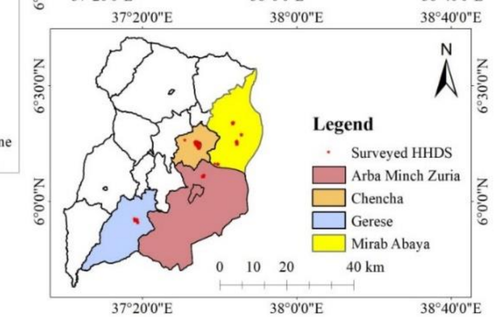


Case Study : Methodology

- Study area (Gamo and Wolaita Zones)
- Desk review
- Household questionnaire, FGD, KII, observation, laboratory analysis
- SPSS, R and Python were used for data analysis
- Household covered 396 (207 biogas user (treatment group) and 189 non-users (control group)
- Control groups has similar socio-economics and demographics (meet eligibility for biogas digester installation)

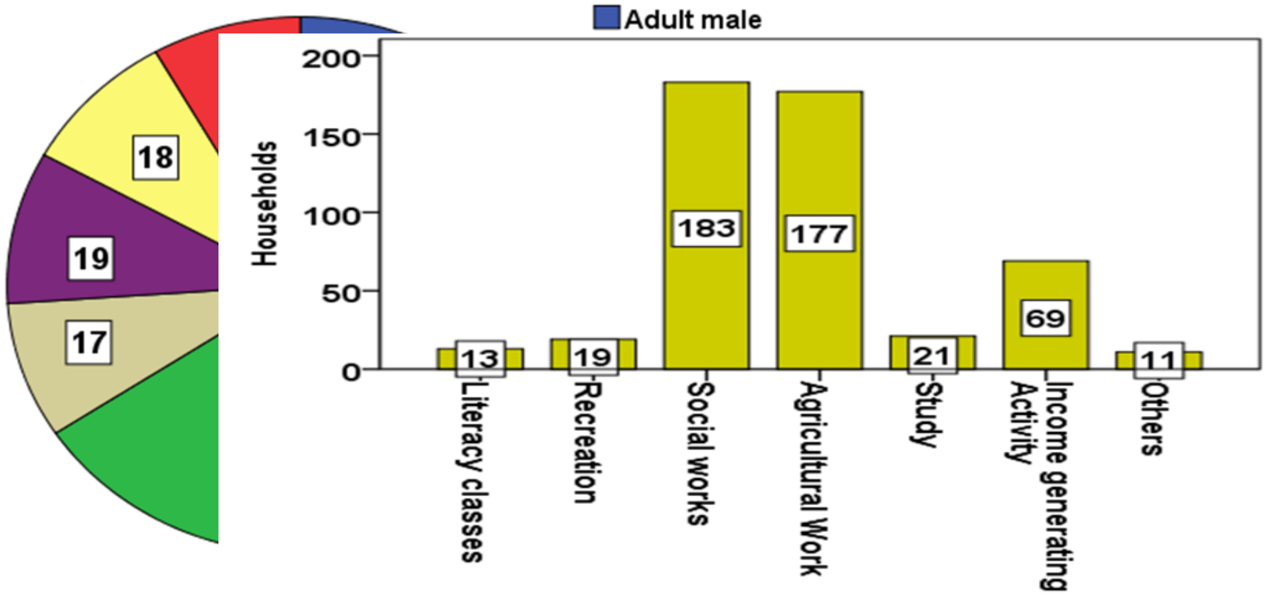




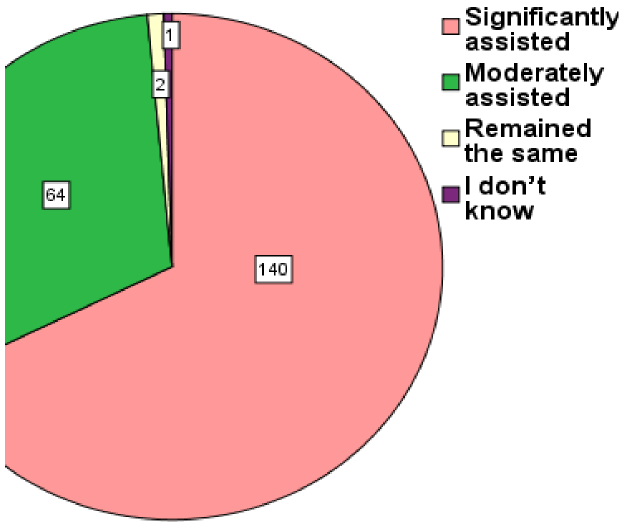


Time saved and gender empowerment

Mitigate+: Research for Low-Emission Food Systems



Person responsible for digester feeding



Time saved due to fast cooking with biogas and clean utensils

Time saved by women from reduced cooking time	69.70 minutes/day 8hrs/week

Factors affecting farm scale biogas adoption

CGIAR Mitigate+: Research for Low-Emission Food Systems

Variable	B	S.E.	Wald	Sig.	Exp(B)
Family size	.108	.047	5.276	.022	1.114
Household education level	.476	.095	25.202	.000	1.609
Connected electricity	-.779	.288	7.300	.007	.459
Availability of underground water in household compound	-.858	.372	5.330	.021	.424
Availability of underground water in community	-1.424	.679	4.398	.036	.241
Household risk taking preferences	.155	.054	8.290	.004	1.168
Cost of nearest office to seek advice on benefits and installation of biogas	.027	.008	11.894	.001	1.027
Feed conservation(hay) practiced	.561	.275	4.150	.042	1.752
Distance from Motorable road	.019	.008	5.326	.021	1.020

Variables that significantly determine biogas adoption

Environmental Defense Fund ILRI CGIAR

Factors affecting farm scale biogas adoption

Mitigate+: Research for Low-Emission Food Systems

Variable	B	S.E.	Wald	Sig.	Exp(B)
Annual total income of households	.000	.000	.117	.732	1.000
Gender of household head	.026	.454	.003	.955	1.026
Cattle holding	-.061	.053	1.332	.248	.941
Land size	.134	.133	1.008	.315	1.143
Energy adequacy	.101	.303	.112	.738	1.107
Compost making practice	.409	.284	2.080	.149	1.506
Altitude (elevation 1172-2765 m)	.000	.000	.769	.381	1.000
Distance from asphalt road	.000	.001	.115	.734	1.000
Distance from Nearest town	.000	.003	.018	.895	1.000
Having own tree farm for firewood	-.009	.273	.001	.974	.991
Constant	.183	2.044	.008	.929	1.201

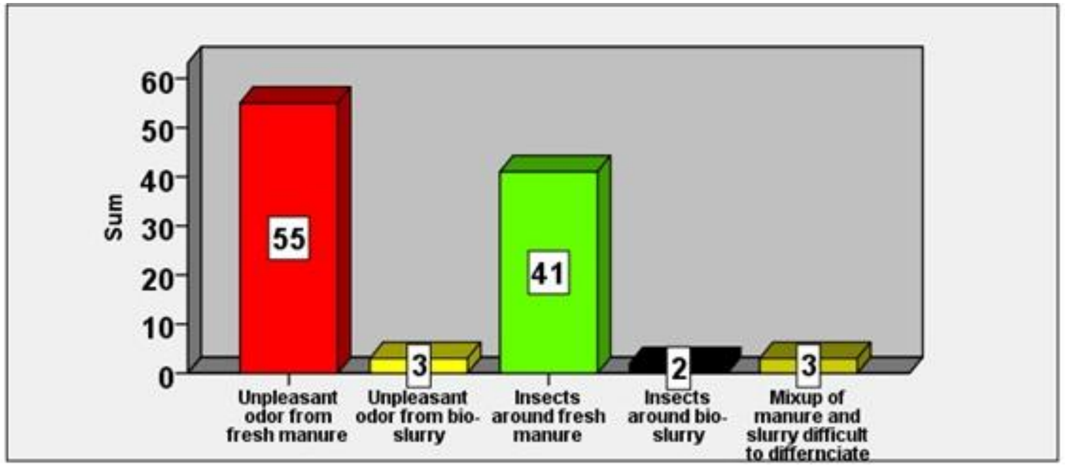
Variables that did not affect biogas adoption

Sanitation status of biogas users and non-users

Variable		Response	Biogas User	Biogas non-user
Sanitation status of toilet	Improved	No.	42	21
		%	**66.7**	33.3
	Moderately improved	No.	111	65
		%	63.1	36.9
	Unimproved	No.	50	97
		%	34.0	**66.0**

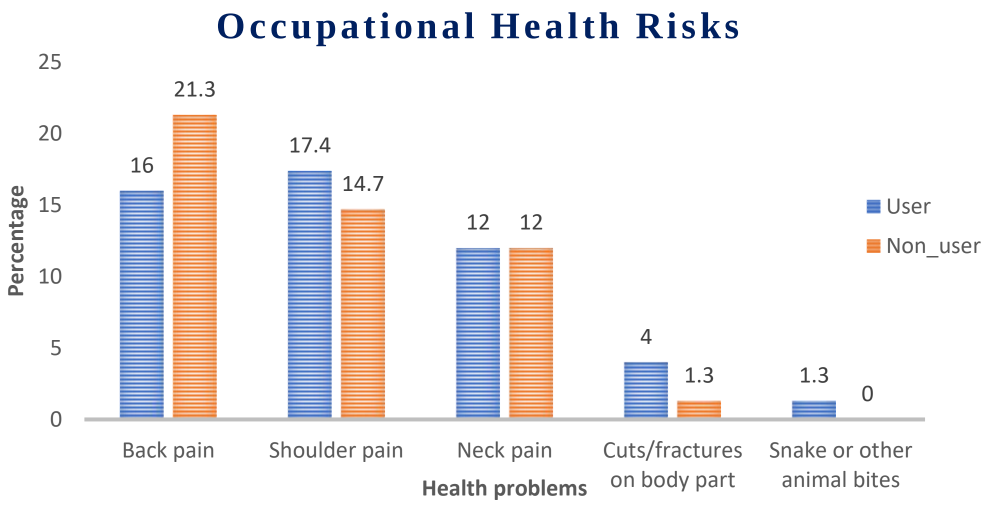
Odor and vectors decrease in bioslurry than fresh manure

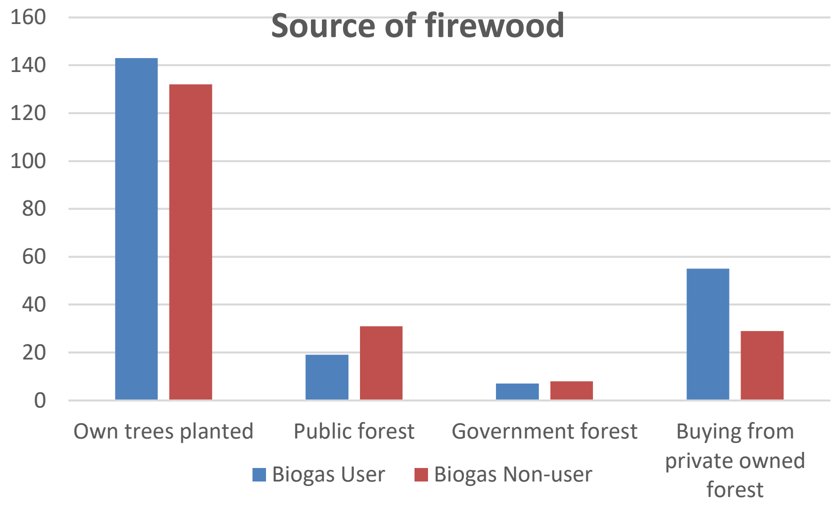
Mitigate+: Research for Low-Emission Food Systems



Occupational Health Risks

Mitigate+: Research for Low-Emission Food Systems





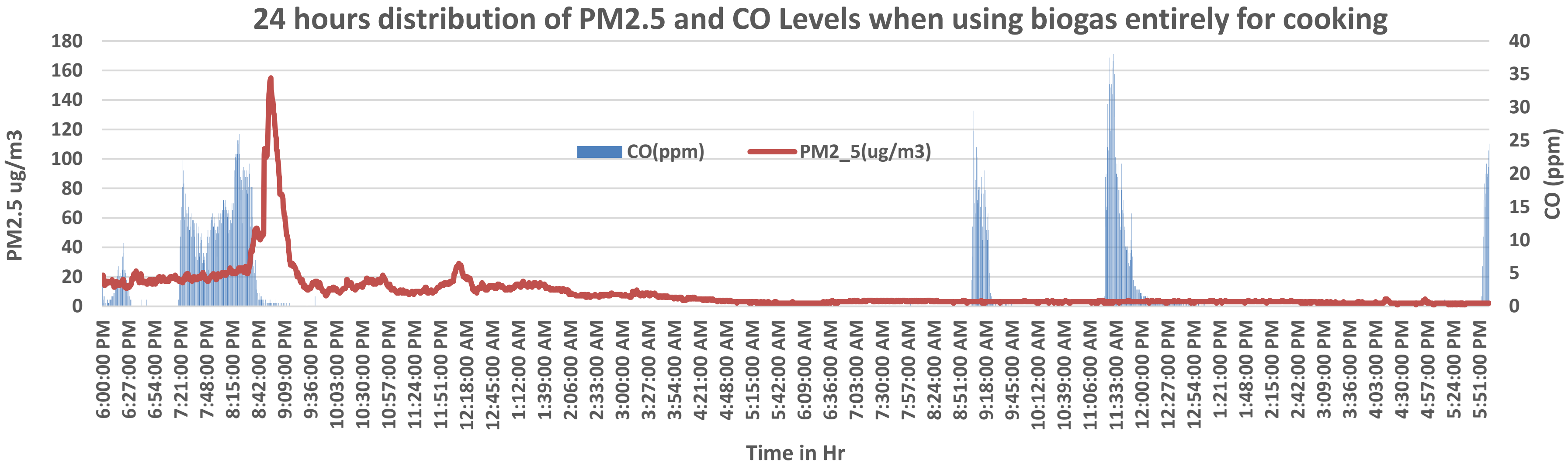
Health impacts of biodigester use

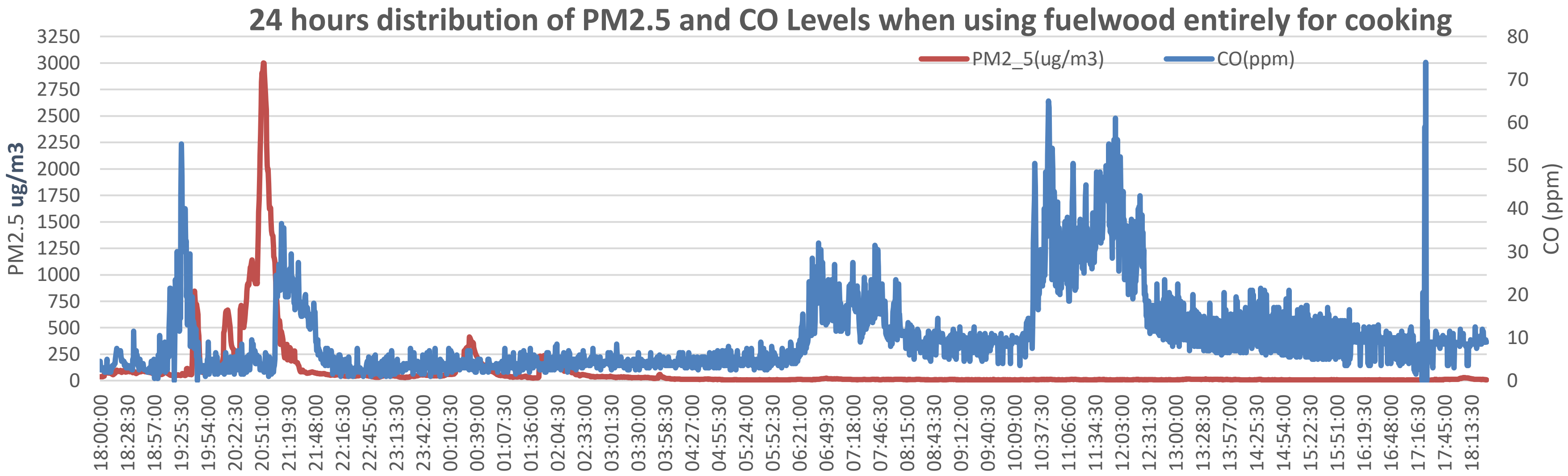
Mitigate+: Research for Low-Emission Food Systems

Variable	Significantly reduced		Reduced		Not reduced		I don’t know	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Biogas plant contributed to reduce incidence of Eye infection	41	62.1%	23	34.9%	0	0.0%	2	3.0%
Biogas plant contributed to reduce incidence of respiratory diseases	42	63.6%	23	34.9%	0	0.0%	1	1.5%
Biogas plant contributed to reduce cause of cough	41	62.1%	22	33.3%	0	0.0%	3	4.5%
Biogas plant contributed to reduce incidence of fire related injury	35	53.0%	25	37.9%	1	1.5%	5	7.6%
Biogas plant contributed to reduce incidence of mosquitos caused diseases	39	59.1%	24	36.4%	1	1.5%	2	3.0%
Biogas plant contributed to reduce incidence of nuisance	38	57.6%	25	37.9%	0	0.0%	3	4.5%

Indoor air pollution levels in biogas and firewood kitchens

Mitigate+: Research for Low-Emission Food Systems





24h average CO trend in biogas vs firewood kitchens

Mitigate+: Research for Low-Emission Food Systems

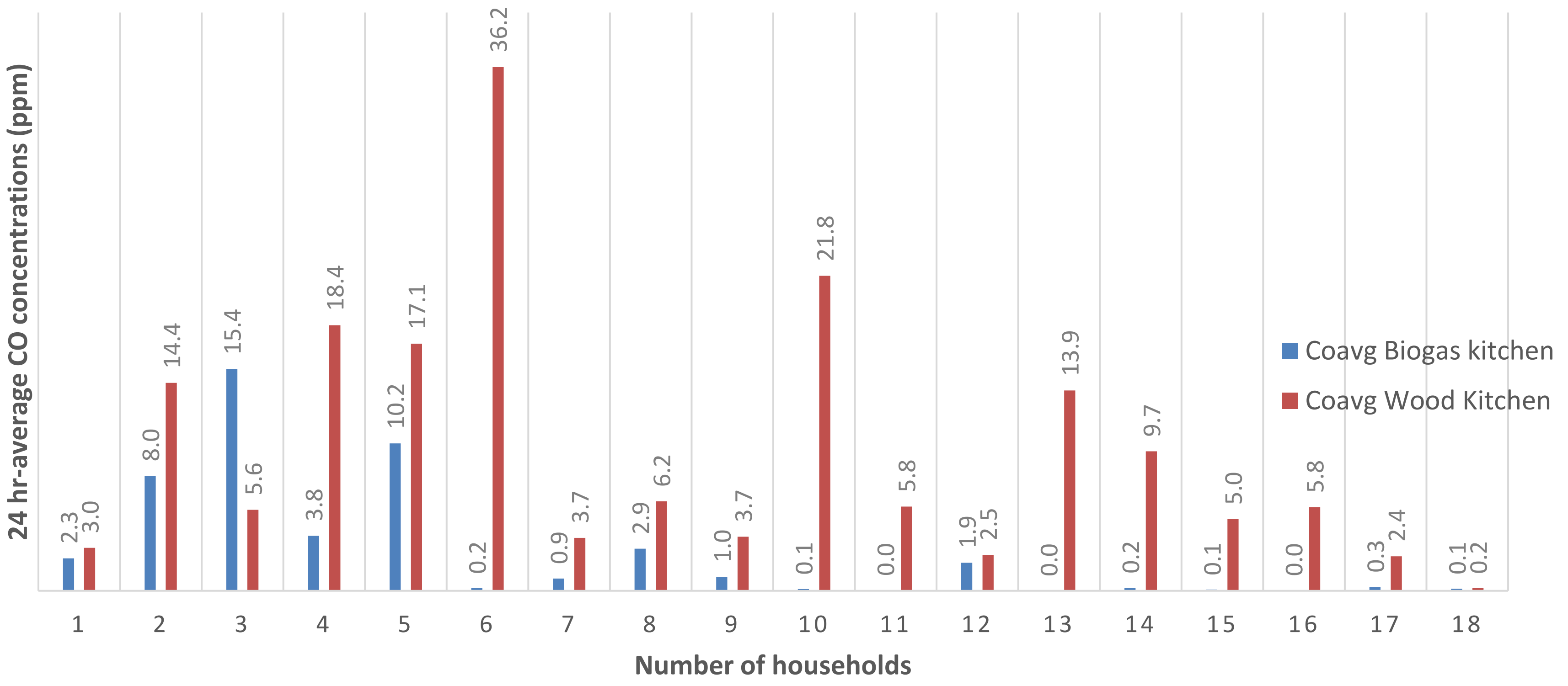
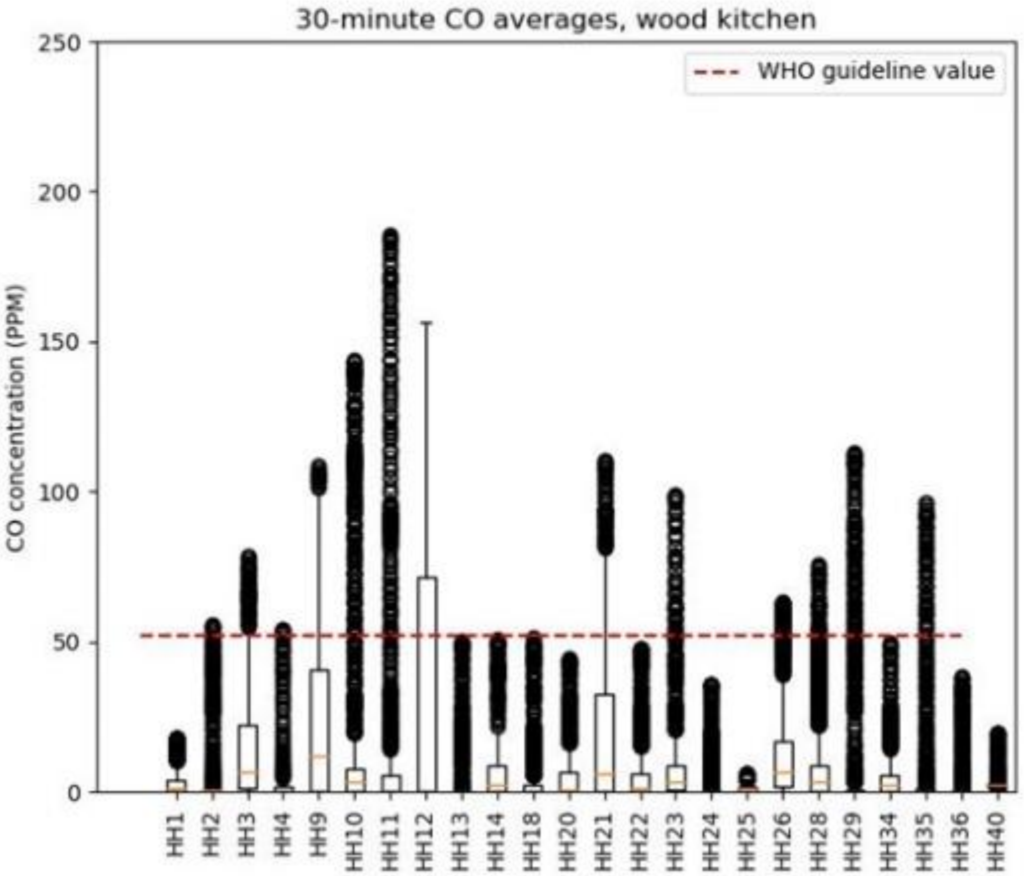


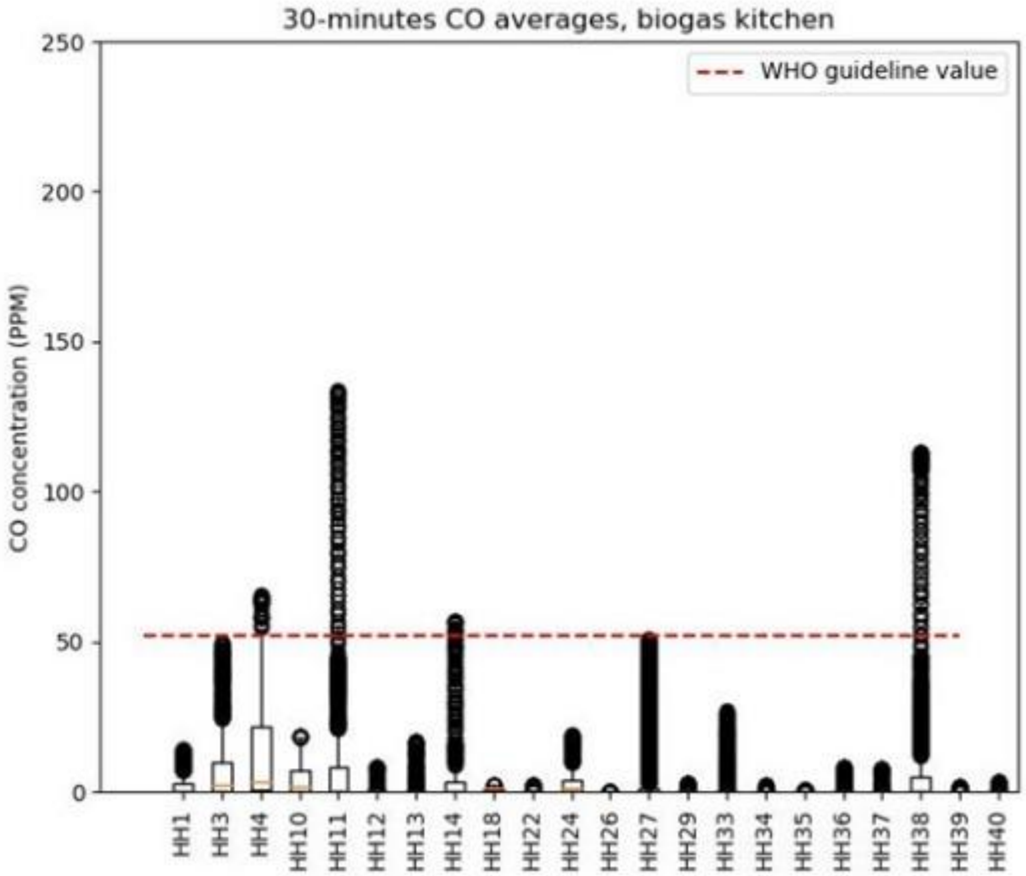
Fig: 24hr avg CO trend in Biogas vs Wood

- The 24h average CO concentration in most firewood kitchens exceeded the WHO limit, while in most biogas kitchens, it was significantly lower than the WHO limit

30 minutes average CO trend biogas and firewood kitchens

Mitigate+: Research for Low-Emission Food Systems





- The 30-minute average CO concentration in most firewood kitchens exceeded the WHO limit, while in most biogas kitchens, it was significantly lower than the WHO limit

Impact of biodigester on pathogen reduction

Mitigate+: Research for Low-Emission Food Systems

Digester design	No of households	Total Coliform, TC (log10)		Fecal Coliform, FC (log10)		%reduction after digestion	
		Fresh manure	Bio-slurry	Fresh manure	Bio-slurry	FC	TC
Toilet connected	12	6.28±0.14	5.64±0.18	5.65±0.31	4.53±0.65	86.94%	74.95 %
Non connected	8	6.22±0.18	5.64±0.14	5.50±0.60	1.96±2.11	99.14%	71.69%

- The level of pathogens in manure significantly reduced after biodigester treatment, with Fecal coliform decreasing by 86.9% - 99.1% and Total coliform by 75.0% - 71.7%.
- Five non-toilet connected and one toilet-connected digester users had no detectable fecal coliform was found after biodigester treatment.

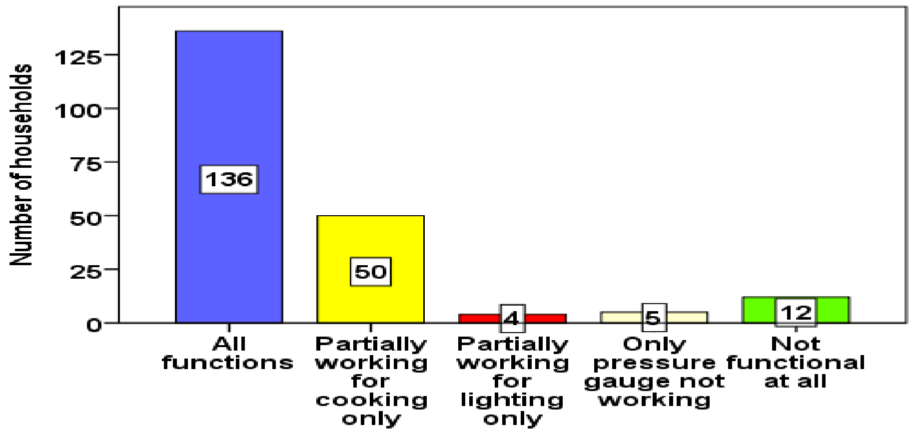
Bioslurry usage as organic fertilizer

Mitigate+: Research for Low-Emission Food Systems

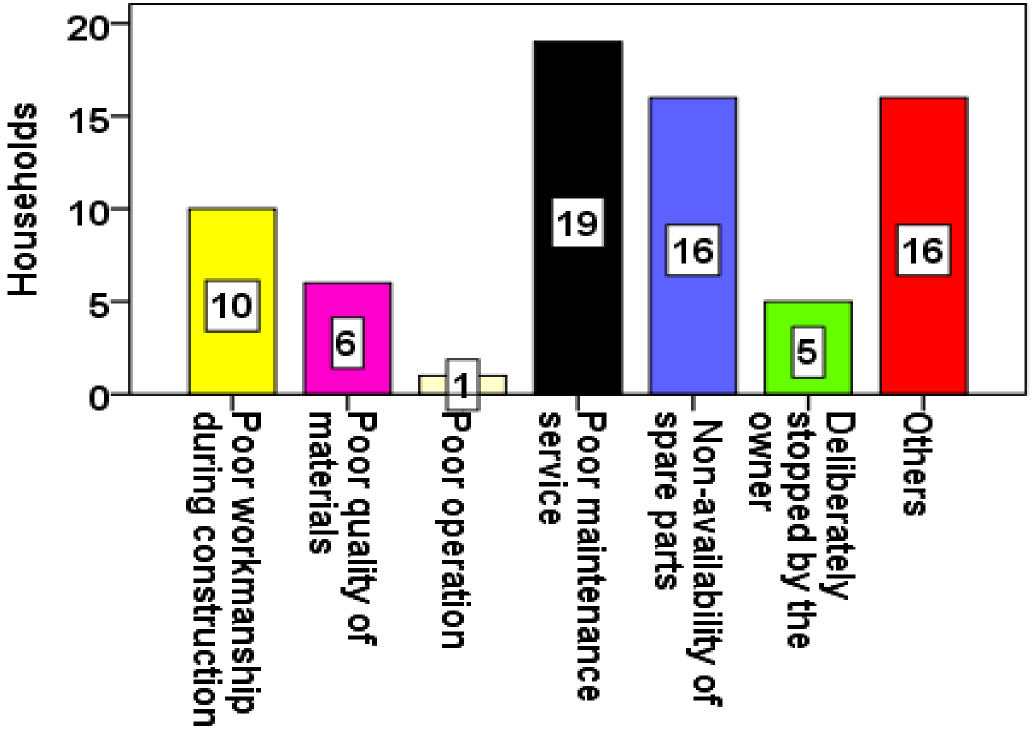
Variable	Responses	No(%)
What are the impacts of slurry manure application on the incidences of insects and diseases on crops?	No Effect	85(41.5)
	Decreased a little	14(6.8)
	Decreased greatly	73(35.6)
	Don't know	33(16.1)
Have you decreased the use of chemical fertilizers after you install your biogas system?	No Effect	21(10.1)
	Decreased a little	23(11.1)
	Decreased greatly	146(70.5)
	Don't know	17(8.2)

Biodigester system functionality

Mitigate+: Research for Low-Emission Food Systems



Level of biogas digester and appliances functionality



The main reasons of the non- functionality of the biogas system

Environmental Defense Fund

ILRI

CGIAR

Cost benefit analysis of biodigester installation

Mitigate+: Research for Low-Emission Food Systems

No	Item	Quantity
1	**Biogas installation cost ($6m^2$) in birr (USD)**	**35000** (629.27)
2	Toilet construction cost	
	Cost of digging toilet $1m^2$	317.74
	Depth of toilet on average(m^2)	6.29
	Average filling period of toilet (years)	5.31
	Toilet construction cost(5.31years)	1998.58
	Cost saved by toilet connected biodigester (birr/month)	**31.37**
3	Energy cost (for cooking)	
	Firewood cost before biogas installation (birr/month)	1601.41
	Charcoal cost before biogas installation(birr/month)	256.82
	Firewood cost after biogas installation (birr/month)	1146.19
	Charcoal cost after biogas installation(birr/month)	152.95
	Energy cost saved (birr/month)	**559.09**
4	Cost of chemical fertilizer	
	Chemical fertilizer before biogas installation (Kg)	87.84
	Chemical fertilizer after biogas installation (Kg)	43.91
	Cost of chemical fertilizer (kg^{-1})	25
	Chemical fertilizer saved per cropping season (kg)	43.93
	Cost of chemical fertilizer saved (in 6months)	1098.25
	Cost of chemical fertilizer saved (birr/month)	**183.04**
5	**Total cost saved (birr/month) (USD)**	**773.5 (13.91)**
6	**Return on Investment (month) (year)**	**45.24 (3.77)**

User satisfaction

Mitigate+: Research for Low-Emission Food Systems

Variable	Very Satisfied		Moderately Satisfied		Not Satisfied	
	No.	%	No.	%	No.	%
Biogas system functioning	178	86.0	26	12.6	3	1.4
Cooking service with biogas plant	161	77.8	39	18.8	7	3.4
Lighting service with biogas plant	154	74.4	29	14.0	24	11.6
Slurry use from biogas plant	168	81.2	30	14.5	9	4.3
Time saving with biogas plant	137	66.2	66	31.9	4	1.9
Health benefits from biogas plant	139	67.1	63	30.4	5	2.4
Environmental benefits from biogas plant	127	61.4	75	36.2	5	2.4

Conclusions

Mitigate+: Research for Low-Emission Food Systems

- Toilet-connected biodigesters significantly improve household sanitation through daily manure cleaning and feeding to digesters, reducing odors from manure and enhancing toilet durability, privacy, and cleanliness.
- Pathogen levels in manure dramatically decrease post-digestion, with Fecal coliforms reduced by 86.9 - 99.1% and Total coliforms by 75.0 - 71.7%.
- Women save 8 hours per week by using biogas from reduced cooking time and cleaning pot, reallocating time to agricultural and social activities.
- Biogas use markedly lowers indoor air pollution: PM2.5 and CO levels in biogas kitchens are well below WHO and Ethiopian standards, in contrast to firewood kitchens.
- Biogas users experience fewer occupational health issues like back pain from improved cooking posture.
- Biogas adoption leads to a 33-40% reduction in fuelwood/charcoal use, yielding significant cost savings.
- The return on investment for biodigesters is approximately 3.7 years, factoring in savings from energy, biofertilizer, and durable toilets.
- Current 6m³ digesters offset 3-5 tons of CO_2e annually, qualifying for the carbon market.
- Adoption of biodigesters reduces chemical fertilizer usage by 50%, enhancing nutrient recycling.

Recommendations

Mitigate+: Research for Low-Emission Food Systems

- Energy stacking remains a challenge; additional clean energy sources are needed to fully meet daily energy needs and achieve SDG7's goal of universal access to clean cooking solutions.
- Improvements in stove design are essential to accommodate various cooking practices.
- Capacity building for users and technicians is crucial, with an emphasis on farmer-to-farmer and technician training programs.
- Developing country-specific emission factors for the biogas sector will enhance the accuracy and integrity of carbon offset calculations in carbon finance.
- Advocacy for research and development in efficient biodigester technologies and best practices is essential.
- Long-term research on indoor air pollution, pathogens along food chains, and self-reported health outcomes in a large number of households is important for the future.
- Implementing financing mechanisms for digesters will increase accessibility for smallholder farmers.
- Integrate best practices for digesters and bioslurry into existing farmer advisory digital platforms and extension services.
- Multi-sectoral implementation of digester programs is crucial, particularly involving agriculture, environment, health and energy ministries.

Daniel Mulat
Environmental Researcher and Lab Manager
d.mulat@cgiar.org
ILRI

Sonja Leitner
Ecologist & Biogeochemist
Soil & Manure Emissions
ILRI

Mazingira Centre
https://mazingira.ilri.org/

Claudia Arndt
Team-Lead
Ruminant Nutrition & GHG Inventories
ILRI

Tegegn Fantahun
PhD Student
AAU

Akiber Wachemo **Demissie Keche**
Zenebe Sahile **Neima Seid**
ABU

Demamu Haligamo
Lecturer, ABU

GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES
KALRO Kenya Agricultural & Livestock Research Organization
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Environmental Defense Fund
CGIAR INITIATIVE ON Low-Emission Food Systems
CGIAR INITIATIVE ON Livestock and Climate
ILRI CGIAR