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Enhancing GHG Reporting in Kenya's Crop Sector

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Table of Contents

Executive Summary

This report presents the outcomes of pilot activities conducted under the Initiative for Climate Action Transparency (ICAT) project in Kenya, jointly implemented by the Alliance of Bioversity International and CIAT and the Ministry of Agriculture and Livestock Development Climate Change Unit (CCU). The project aimed at strengthening the reporting of greenhouse gas (GHG) emissions in the crop sub-sector by improving Kenya's capacity to collect and utilize detailed farm-level activity data for Tier 2 reporting, aligned with IPCC guidelines, thereby enhancing the accuracy and transparency of national GHG inventories.

A key achievement of the project was the development and piloting of a digital GHG activity data collection tool designed to gather granular data on key agricultural practices such as fertilizer and manure use, crop residue management, tillage, agroforestry, and liming. This tool was piloted with farmer groups in five counties—Murang'a, Makueni, Taita Taveta, Nyamira, and Baringo—enabling the collection of location-specific data critical for improved emission estimation. Capacity building was integral to the project, including training agricultural officers and ward-level extension staff in data collection and management. To facilitate data integration and aggregation at higher administrative levels, a dedicated GHG activity data module was integrated into the existing Climate Smart Agriculture Reporting Tool (CSART)— developed under a previous ICAT project to support reporting on adaptation measures—providing a platform for easy integration, storage, and analysis of the independently collected GHG data across ward, sub-county, and county levels.

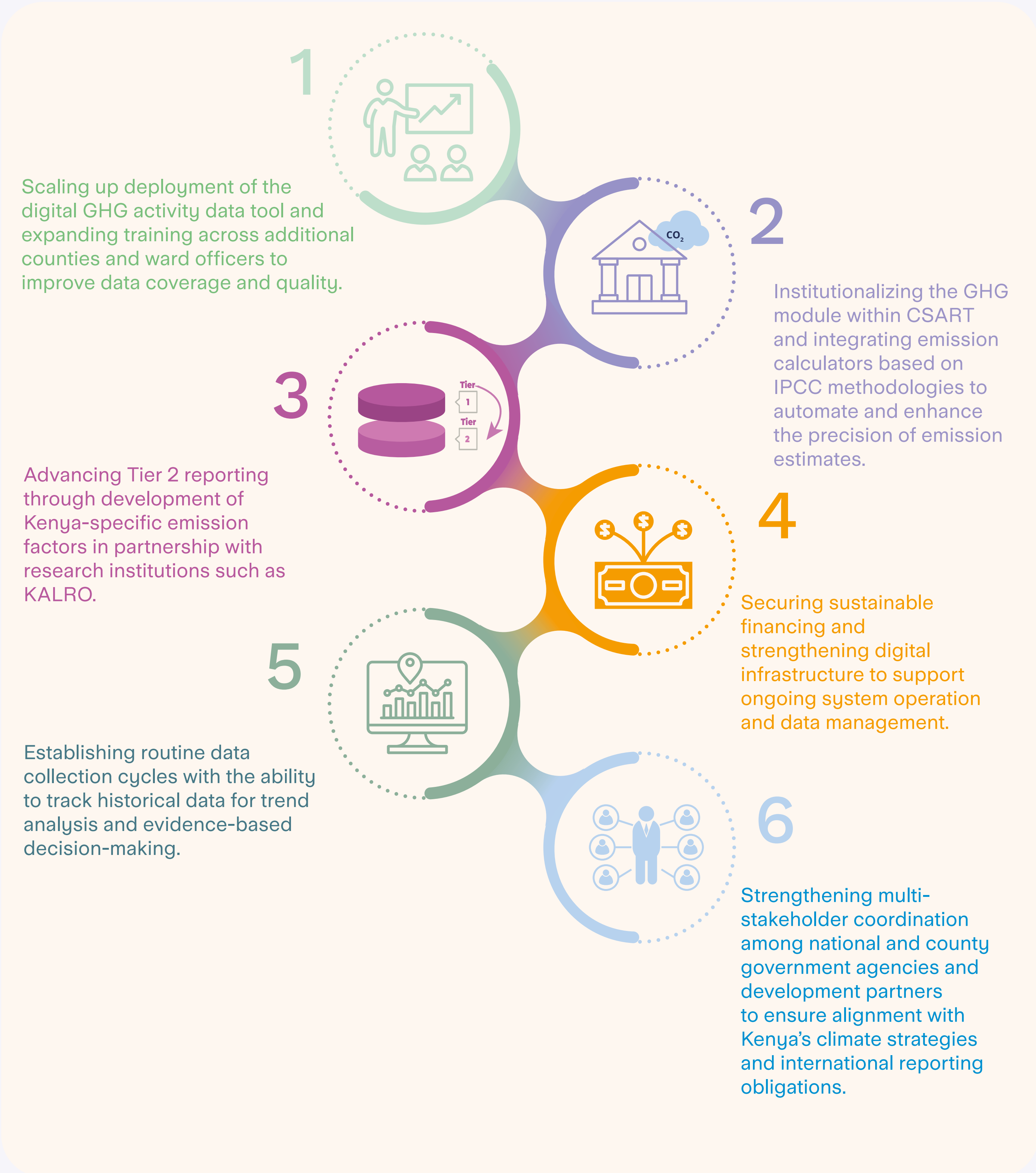
The project also incorporated a policy analysis which revealed gaps between Kenya's agricultural and environmental policies and the availability of reliable, field-level data necessary for effective implementation and climate reporting. Most policies lack empirical grounding in localized farming data, limiting their ability to inform greenhouse gas inventories or mitigation outcomes accurately. Embedding digital tools like the GHG module within institutional frameworks such as CSART presents a pathway to close this data-policy gap and improve transparency in climate action reporting. To support Kenya's Nationally Determined Contribution (NDC) goals, which emphasize Climate-Smart Agriculture (CSA) to meet mitigation and adaptation targets, this integrated system enables systematic collection and analysis of regularly updated data on land management and farming practices. This capability provides an easy platform for tracking and updating NDC's targets.

The project team proposes the establishment of a robust institutional framework led by the Climate Change Unit (CCU), in collaboration with county governments, research institutions, and the Climate Smart Agriculture Multi-Stakeholder Platform (CSA-MSP). This framework would coordinate data compilation, validation, and modelling processes, ensuring data quality and scientific rigor in inventory reporting.

Key recommended next steps to enhance and operationalize the system include:

- Scaling up deployment of the digital GHG activity data tool and expanding training across additional counties and ward officers to improve data coverage and quality.
- Institutionalizing the GHG module within CSART and integrating emission calculators based on IPCC methodologies to automate and enhance the precision of emission estimates.
- Advancing Tier 2 reporting through development of Kenya-specific emission factors in partnership with research institutions such as KALRO.
- Securing sustainable financing and strengthening digital infrastructure to support ongoing system operation and data management.
- Establishing routine data collection cycles with the ability to track historical data for trend analysis and evidence-based decision-making.
- Strengthening multi-stakeholder coordination among national and county government agencies and development partners to ensure alignment with Kenya's climate strategies and international reporting obligations.

Overall, this initiative demonstrates the feasibility and value of combining independent, digital data collection with integrated reporting platforms to improve the quality and transparency of Kenya's agricultural GHG inventory. By enhancing institutional capacity and enabling data-driven climate action, the project lays a strong foundation for scaling this system nationwide to support Kenya's ongoing climate commitments and sustainable agricultural development.



1: Introduction

The Initiative for Climate Action Transparency (ICAT) funded an 18-month project aimed at improving greenhouse gas (GHG) reporting in Kenya's crop subsector, focusing on the transition from Tier 1 to Tier 2 reporting. The project was implemented by the Alliance of Bioversity International and CIAT, in collaboration with the Climate Change Unit of the Ministry of Agriculture and Livestock Development (MOALD). Key activities included producing a roadmap to guide the transition to Tier 2 reporting and conducting a comprehensive policy analysis to assess how existing climate, agriculture, and environmental policies support the GHG inventory process (Ndetu & Nyawira, 2024; Ndetu et al., 2024). Additionally, the project developed a data collection tool for gathering Tier 2 activity data necessary for estimating GHG emissions in the crop subsector.

The agricultural sector plays a pivotal role in global greenhouse gas emissions, with agriculture, forestry, and other land-use (AFOLU) activities collectively accounting for a large share of anthropogenic emissions. According to the Intergovernmental Panel on Climate Change Sixth Assessment Report, the global food system contributes approximately 21% to 37% of total net anthropogenic greenhouse gas emissions (IPCC, 2022), — a share that is expected to increase with population growth and as other sectors decarbonize more rapidly. Agriculture itself contributes about one-third of global GHG emissions, driven by crop cultivation, livestock management, land-use changes, and associated processes.

In Kenya, the agricultural sector is a key contributor to GHG emissions. For instance, in 2022, agriculture contributed approximately 36 Mt CO_2 eq., representing around 32% of the country's national emissions, with the AFOLU sector as a whole accounting for 73% of Kenya's total emissions (MOECCF, 2024). This reflects a 131% increase in agricultural emissions since 1990, largely driven by expanding agricultural land, deforestation, increased fertilizer use, and rising livestock numbers. Major agricultural emission sources in Kenya include enteric fermentation from livestock (87%), agricultural soils (6%), and manure management (approximately 5.6% when methane and nitrous oxide are combined) (MOECCF, 2024).

Under the Paris Agreement, all signatory countries are required to regularly compile and communicate their GHG inventories to track progress toward Nationally Determined Contributions (NDCs) (UNFCCC, 2015). Kenya, like other developing countries, must submit Biennial Transparency Reports (BURs) as part of its obligations under the United Nations Framework Convention on Climate Change (UNFCCC). Kenya has committed to reducing its GHG emissions by 32% by 2030, underscoring the importance of transparent, accurate, and timely GHG reporting (Government of Kenya, 2020). IPCC methodologies are central to ensuring that the data used in reporting is comparable and reliable, facilitating national and international climate action efforts (IPCC, 2006; IPCC, 2019). At the national level, accurate GHG data is essential for guiding mitigation and adaptation strategies, aligning them with broader development goals, and monitoring progress over time. Within the Enhanced Transparency Framework (ETF), Kenya is striving to establish robust monitoring, reporting, and verification (MRV) arrangements that support its mitigation and adaptation efforts. While three GHG inventories have already been submitted, the country is working to strengthen its MRV framework to better track progress toward its NDC commitments.

Despite strong mitigation ambitions in Kenya's NDCs, especially in the agricultural sector, progress is constrained by the limited availability of comprehensive, high-resolution activity data. A recent policy analysis under the ICAT project revealed key gaps, including misalignment between existing activity data and emission reduction targets (Ndetu et al., 2024). Although Kenya has numerous climate-smart agriculture and environmental policies, they often lack the granular data required to quantify mitigation outcomes, particularly at the subnational level.

Kenya's crop subsector currently uses Tier 1 methods relying on default emission factors and generalized activity data, which provide less accurate estimates (IPCC, 2006). For example, fertilizer and manure emission factors do not reflect local variations in crop types or regional climate. Tier 1 also overlooks critical practices like tillage, cover cropping, and agroforestry, limiting comprehensive emissions accounting. This lack of specificity hampers effective assessment of mitigation actions, identification of emission hotspots, and measurement of policy impacts in the crop subsector. Transitioning to higher-tier methodologies will yield more precise emissions data, better supporting Kenya's climate action planning and NDC commitments.

The ICAT GHG project addresses these challenges by developing and implementing a data collection tool for Tier 2 activity data in the crop subsector. This tool captures detailed, locally relevant information to improve the accuracy of emissions estimates and enhance transparency in reporting. Training was provided to agricultural officers across five counties in Kenya, and the tool was piloted with selected farmer groups to ensure practicality and usability (Nyawira et al., 2024). By integrating the tool into Kenya's existing reporting platform under the Kenya Climate-Smart Agriculture Monitoring and Evaluation Framework, the project enhances access to relevant activity data. This supports more effective tracking and updating of climate actions in the crop subsector, aligned with Kenya's NDCs and international reporting obligations (MoAFLC, 2021).

This report presents an overview of the progress made in developing and pilot-testing the activity data collection tool, demonstrates how the collected data can improve inventory accuracy through sample calculations, and outlines the integration of the tool into Kenya's existing reporting platform under the Kenya Climate-Smart Agriculture Monitoring and Evaluation Framework (MoAFLC, 2021)..

2. Activity data for GHG reporting in Kenya's crop subsector

2.1 Activity data requirements for emissions reporting

Managed soils contribute to greenhouse gas emissions, with nitrous oxide (N_2O) and methane (CH_4) being the primary sources of emissions. N_2O emissions from agricultural activities primarily stem from the application of synthetic fertilizers, manure management, and crop residue decomposition. According to the IPCC Guidelines, N_2O emissions are classified into direct and indirect sources. Direct emissions occur when nitrogen inputs, such as fertilizers and manure, undergo microbial nitrification and denitrification in soils, releasing N_2O. Indirect emissions result from nitrogen leaching, runoff, and volatilization, where nitrogen compounds are transported and subsequently converted into N_2O in other ecosystems. Additionally, rice paddies are a major source of CH_4 emissions, as anaerobic conditions in flooded soils promote microbial methanogenesis (IPCC, 2006).

The IPCC Guidelines provide a tiered approach to estimating N_2O and CH_4 emissions, ranging from simpler methods in Tier 1 to more detailed, country-specific estimates in higher tiers. Tier 1 uses default emission factors and broad activity data, whereas higher tiers incorporate more specific data to enhance accuracy. In Tier 1, emissions are estimated using global default emission factors based on broad categories, such as synthetic fertilizer application, manure management, crop residue decomposition, and methane emissions from rice paddies. These factors are based on global averages and do not account for local variations in soil types, climate, cropping systems, or management practices. Activity data for Tier 1 typically includes national-level statistics, such as total fertilizer consumption, cropland area, and overall rice production. This approach, while simple and accessible, is limited in precision and does not capture regional or site-specific differences. As a result, it is more suitable for countries with limited data but less effective for those seeking accurate greenhouse gas inventories (IPCC, 2006; IPCC, 2019).

Tier 2, on the other hand, improves accuracy by incorporating country-specific data and emission factors tailored to local conditions. For N_2O emissions, Tier 1 uses a single emission factor for all nitrogen inputs, which does not differentiate between organic and inorganic fertilizers or account for differences in their decomposition rates. In contrast, Tier 2 refines these estimates by using differentiated emission factors for various fertilizer types, such as synthetic fertilizers versus manure-based inputs, and adjusts calculations based on site-specific factors, including soil texture, crop type, and climate conditions (IPCC, 2006). In addition, the activity data is more disaggregated.

For CH_4 emissions from rice paddies, Tier 1 applies a default emission factor for flooded fields, whereas Tier 2 incorporates region-specific data, considering factors such as water management practices, organic matter content, and soil characteristics. Furthermore, Tier 2 provides a more accurate representation of indirect emissions from nitrogen leaching, runoff, and volatilization, using national or regional studies on nitrogen transport dynamics rather than relying on generalized global assumptions (IPCC, 2019).

2.2 Current data used for GHG reporting in Kenya's crop subsector

Kenya currently employs a Tier 1 approach for estimating greenhouse gas (GHG) emissions in the crop subsector. The national inventory includes estimates of both direct and indirect N_2O emissions from synthetic fertilizers and manure applications, CO_2 emissions from the application of urea and lime, CH_4 emissions from rice cultivation, and emissions from biomass burning, which are currently reported only for sugarcane. The data for synthetic fertilizer usage is derived from distribution records maintained by the Ministry of Agriculture and Livestock Development (MOALD), while cropland areas are obtained from MOALD's agricultural databases. The inventory covers key crops such as maize, beans, rice, wheat, sorghum, millet, Irish potatoes, sugarcane, cotton, coffee, and tea, with fertilizer application rates varying depending on the specific crop type (Table 1). Annual crop residue data is sourced from FAOSTAT, while nitrogen inputs from livestock (including urine and dung deposition on grazed soils) are estimated using livestock population data provided by Kenya's State Department of Livestock.

Although emissions from soil mineralization and organic soil drainage are not currently included in Kenya's GHG inventory, biomass burning emissions are considered. However, biomass burning emissions are only reported for sugarcane cultivation. The relevant data on area under sugarcane that is burned is obtained from the Food and Agriculture Organization (FAO). For the fertilizer emissions, uniform fertilizer application rates are assumed, with variations primarily observed between food crops and perennial crops (Table 1).

Direct N_2O emissions from managed soils are calculated using Equation 11.1 in the IPCC 2006 Guidelines, which accounts for emissions from synthetic fertilizers, manure application, crop residues, managed organic soils, and urine/dung deposition on grazed land. However, Kenya's current inventory only captures emissions from synthetic fertilizers and nitrogen contributions from crop residues. Emissions resulting from soil mineralization and organic soil drainage are not included. Indirect N_2O emissions, arising from nitrogen leaching and atmospheric deposition are also included. 10% of the lime produced in Kenya is used for crop production, and CO_2 emissions from lime application are estimated according to the guidelines. All emission estimates are based on default IPCC emission factors.

Table 1: The crops included in the recent inventory for Kenya and the assumed fertilizer application rates (kg/ha) used to estimate GHGs emissions, including both planting and top-dressing fertilizers.

	Planting		Top dressing
Crop	**DAP**	**NPK**	**CAN**
Maize	124	-	124
Beans	-	124	-
Millets	124	-	124
Sorghum	124	-	124
Rice	124	-	124
Coffee	-	247	-
Tea	-	247	-
Potatoes	124	-	124
Wheat	124	-	124
Cowpeas	-	124	124
Sugarcane	124		124

2.3. New activity data collection tool

2.3.1 Summary of the tool

Kenya's Ministry of Agriculture, Livestock, and Fisheries (MOALD) currently lacks a structured routine for systematically collecting activity data from farmers at the ward, sub-county, and county levels. This absence, coupled with the lack of a comprehensive GHG emissions inventory system, has made it challenging to accurately report emissions. As Kenya transitions from a Tier 1 to a Tier 2 approach for GHG inventory reporting, more detailed, farm-level data is required on management practices and inputs affecting GHG emissions. To facilitate this transition, a detailed survey tool was developed to enable efficient, structured, and accurate data collection. The GHG data collection tool was designed using the SurveyCTO platform, with survey questions structured in an Excel form and uploaded to the platform. The tool enables farm-level data collection, ensuring more accurate and context-specific GHG assessments. It addresses significant data gaps by capturing detailed information on farming practices and management practices that can be used for Tier 2 reporting.

The tool collects comprehensive data on aspects such as crop area, the main crops grown, manure application sources, fertilizer types, specific application rates, liming practices, livestock production, area burnt, biomass, residue management, agricultural machinery use, agroforestry (tree species, numbers, and ages), and rice management (Mwangi & Nyawira, 2025). This tool is compatible with android devices and designed to function offline, allowing enumerators to work in areas without internet connectivity. Upon downloading the tool, enumerators log in with their credentials and download the assigned survey form. During data collection, enumerators navigate through the digital form to capture farmer responses. The platform features both auto-save and manual save options to ensure data integrity, while built-in constraints, validations, and skip logic enhance the accuracy of data entry. GPS coordinates are automatically recorded to support location-based specifications. Once data collection is complete, enumerators upload the finalized forms when internet access becomes available.

2.3.2 Development process of the tool

The development of the SurveyCTO GHG data collection tool was guided by the IPCC Tier 2 guidelines, which require more detailed and country-specific GHG accounting compared to Tier 1 (Mwangi and Nyawira, 2025). The development process focused on identifying the specific data required for a comprehensive Tier 2 inventory in the crop subsector. The tool was designed with close consideration of the IPCC 2006 Guidelines for National Greenhouse Gas Inventories to ensure it captures the appropriate data needed for Tier 2 emissions estimates. The tool collects detailed farm-level management data to strengthen comprehensive emission estimates for the crop subsector and and improve policy formulation for climate mitigation in Kenya's agriculture sector.

The data requirements were then translated into key questions that were structured according to the categories that they fall under. The SurveyCTO questionnaire tool was developed through a collaborative process involving key stakeholders.

These included ward, sub-county, and county agricultural officers, livestock, environment, and data units within each county, representatives from the Kenya Climate Smart Agriculture Multi-Stakeholder Platform (CSA-MSP), members from the Ministry of Agriculture, Livestock, and Fisheries' Climate Change Unit (MOALD-CCU), and researchers from the Alliance of Bioversity International and CIAT.

2.3.3 Piloting the tool in five counties

The piloting of the activity data collection tool began in Murang'a County to assess its effectiveness and identify initial gaps in data collection. Based on feedback from this initial phase, the tool was refined to address identified shortcomings and then rolled out to five counties: Taita Taveta, Makueni, Baringo, Murang'a, and Nyamira. These counties were selected because they had previously participated in another ICAT-funded initiative that supported the development of the Kenya Climate-Smart Agriculture Monitoring and Evaluation Framework reporting tool (MoAFLC, 2021).

Capacity-building workshops were conducted across the five counties, in collaboration with local agricultural offices and ward administrators. A total of 99 agricultural officers were trained (Mwangi et al., 2024). The workshops covered Kenya's GHG inventory process, relevant policies, and the institutional arrangements governing national reporting frameworks. A core focus of the training was the new data collection tool—participants were introduced to the type of data it collects and how it enhances the transition from Tier 1 to Tier 2 GHG reporting in the crop subsector.

The tool was deployed among farmer groups within each ward, resulting in interviews with 331 farmers (Table 2)[1] . The broader piloting phase across the five counties revealed additional data needs, leading to further refinements of the tool. Notably, questions on manure production, livestock numbers, and crop yields were incorporated to improve the tool's comprehensiveness and support more accurate emissions estimates in future reporting cycles.

Table 2: Summary of farmers and administrative units (wards, sub-counties, and counties) who participated in the pilot.

County	Sub County	Ward	No. of farmers
Taita Taveta	Taveta	Mboghoni	57
	Mwatate	Bura, Chawira	25
Baringo	Eldama Ravine	Pekerra, Ravine	20
	Mogotio	Mogotio	15
Nyamira	Nyamira South	Magombo	34
	Manga	Bosamaro	35
Murang'a	Kahuro	Maragwa	34
	Kiharu	Wangu	30
Makueni	Makueni	Kathonzweni	23
		Kanzokea	20
	Mbooni	Tulimani	20
		Mbooni	18
Total			**331**

1 https://dataverse.harvard.edu/privateurl.xhtml?token=e2e9be7c-3e9a-4f69-a6f8-1503965d2f86

2.4. GHG emission estimation using activity data from pilot counties

Estimation of greenhouse gas (GHG) emission from collected data focused on N_2O emissions from fertilizer, manure applications. Emissions from crop residues were not included in this analysis. In addition, we estimated N_2O and CH_4 emissions associated with maize biomass burning. The following section outlines the approach used for estimating and comparing emissions from fertilizer and manure applications.

2.4.1 N_2O emissions from fertilizer application

To estimate N_2O emissions resulting from fertilizer application, we used three different approaches:

1. **Tier 1 (Current MOALD Approach)**: This method follows the existing Tier 1 approach used by the Ministry of Agriculture and Livestock Development (MOALD). It assumes uniform fertilizer application rates across all croplands for Di-Ammonium Phosphate (DAP), Nitrogen Phosphorous and Potassium (NPK), and Calcium Ammonium Nitrate (CAN), as shown in Table 1. The total area under each crop was used to estimate the emissions. The default IPCC emission factors were applied to estimate both direct and indirect N_2O-N emissions.

2. **Improved Tier 1:** This approach builds on the Tier 1 method by incorporating actual fertilizer application rates reported by farmers. These rates vary by fertilizer type and county, as evident in Table A1 for selected crops. Emissions were estimated using the median fertilizer application rate for each county, while retaining the default IPCC emission factors for both direct and indirect N_2O-N emissions. For this approach, the area under each specific fertilizer type was considered in the calculations to estimate emissions for different fertilizer types.

3. **Tier 2 (maize only):** This approach utilized local application studies conducted within Kenya, which provided a range for N_2O-N emissions of 0.004–0.013 kg N_2O-N per kg N applied. This allowed for a more region-specific estimate of emissions compared to the default IPCC emission factors.

In the Tier 1 (current MOALD approach), we estimated emissions using the total cultivated area for each crop reported by interviewed farmers. In contrast, under the improved Tier 1 method, we used only the crop areas where farmers explicitly reported applying fertilizer. This means the areas considered for estimating fertilizer-related emissions differed between the two approaches.

Direct N_2O-N input emissions (first part of Equation 11.1 in the guidelines) were calculated by first determining the total nitrogen applied per fertilizer type. The nitrogen content was assumed to be 18% for DAP, 10% for NPK, and 26% for CAN. Since urea application rates were low among interviewed farmers (Table A1), emissions from urea were not included in the estimation. To calculate N_2O-N inputs emissions, the total nitrogen applied was multiplied by the cropland area under each fertilizer type for the improved Tier 1 approach, and by the total cropland area under each crop for the Tier 1 approach. The respective emission factors were then applied.

For direct emissions, the default IPCC emission factor is 0.01 kg N_2O-N per kg of nitrogen applied (IPCC, 2006) was applied for in approach 1 while in approach three we used the minimum (0.005 kg N_2O-N per kg) and maximum (0.014 kg N_2O-N per kg) emission factors published in Lemarpe et al., 2021 for maize systems in Kenya. The resulting N_2O-N emissions were then converted to N_2O using the molecular weight ratio of 44/28 and further converted to CO_2-equivalents (CO_2 eq.) using the Global Warming Potential (GWP) of 273, as reported in the IPCC AR6 report. Indirect N_2O-N emissions were estimated using Equations 11.9 and 11.10 from the IPCC guidelines. Based on IPCC recommendations, it was assumed that 10% of applied nitrogen was volatilized and 30% of applied nitrogen was leached. The default IPCC emission factors were used: 0.01 kg N_2O-N per kg N volatilized (for volatilized and redeposited nitrogen) and 0.0075 kg N_2O-N per kg N leached (for leached nitrogen).

Rice cultivation was reported only in Taita Taveta, where all interviewed farmers practiced upland rice farming. According to the IPCC guidelines, CH_4 emissions from rice cultivation are primarily associated with flooded (paddy) fields. Since upland rice is grown in non-flooded, aerobic soils, it is not considered a source of methane emissions (IPCC, 2006). Therefore, we treated upland rice similarly to other crops, considering only N_2O emissions resulting from fertilizer and manure applications.

2.4.2 N_2O emissions from manure application

For manure application, emissions were estimated using only the Improved Tier 1 approach. The total amount of manure applied to each cropland was standardized to kilograms per hectare (kg/ha) (see rates in Table A4). Median application rates per farm were used to calculate emissions (Table A2).

The nitrogen content in manure was assumed to be 1.36%, a value derived from the average of published literature estimates for different manure types—including cattle, poultry, and goat manure (Lekasi et al., 2001). Direct N_2O emissions from manure application were calculated by multiplying the nitrogen content by the default IPCC emission factor of 0.01 kg N_2O-N per kg of nitrogen applied.

For indirect emissions, it was assumed that 20% of the applied nitrogen volatilizes and 30% is lost through leaching and runoff. These values, drawn from the 2019 Refinement to the 2006 IPCC Guidelines, were used together with the corresponding default emission factors to estimate indirect N_2O emissions from manure application, consistent with the methodology applied for fertilizer use.

2.4.3 N_2O and CH_4 emissions from burning maize residues

Emissions from crop residue burning included in the inventory for Kenya are only for sugarcane. However, from the pilot data, we were able to estimate emissions from burning maize residues. The pilot data provided information on the area under maize cultivation and the percentage of the residues burnt. To estimate the biomass of the residual burnt, we used CIAT Long-term trials in western Kenya (with 46 cropping seasons) maize data under different management. The trials have different tillage practices, use and no use of Farm Yard Manure (FYM), different fertilizer and application rate, and use and no use of mulch. From the data we estimated the average biomass under different management systems. The average biomass was used to estimate maize stover biomass under similar management. This biomass was then multiplied by the reported percentage of residue burned to estimate the biomass burned in the farms. Equation 2.27 in the IPCC guidelines was then used to estimate emissions from the burning. Default combustion and emission factors were used in the estimates.

EQUATION 2.27

ESTIMATION OF GREENHOUSE GAS EMISSIONS FROM FIRE

$$L_{fire} = A \bullet M_B \bullet C_f \bullet G_{ef} \bullet 10^{-3}$$

Where:

L_{fire} = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH_4, N_2O, etc; A = area burnt in ha; M_B is the mass of fuel available for combustion in tonnes ha^{-1}. This includes biomass, ground litter and dead wood;

C_f = combustion factor; G_{ef} = emission factor, g kg^{-1} dry matter burnt. Note: Where data for MB and Cf are not available, a default value for fuel actually burnt (the product of M_B and C_f) can be used under Tier 1 methodology.

2.5 Fertilizer, manure and burning emission estimates

The analysis revealed significant differences in emissions from fertilizer application depending on the estimation approach used. In all five counties—except for beans in Baringo County—emissions estimated using the standard Tier 1 approach, which applies uniform fertilizer rates across the entire cropland area, were consistently higher than those estimated using the Improved Tier 1 approach. The Improved Tier 1 method considers the actual area under each specific fertilizer type (Table 3). Using uniform national values in the standard Tier 1 approach results in identical emissions per hectare for each crop across all counties. In contrast, the improved Tier 1 approach, which reflects variations in fertilizer types, application rates, and area coverage, produces more differentiated and realistic emission estimates per hectare. These findings suggest that the use of national-level default values in the Tier 1 approach likely leads to overestimation of GHG emissions from fertilizer use in Kenya. Consequently, this may result in mitigation targets that are aligned with actual farmer practices.

By capturing variability in fertilizer application practices and crop coverage, the improved Tier 1 method better represents farmer practices. Although not shown here, additional estimates for crops not included in the national inventory highlight the difference in emissions per hectare for these crops. For example, in Makueni County, a significant proportion of farmers cultivate green grams and pigeon peas (Table A3), which also contribute to fertilizer-related emissions. Including such variability in crop production and fertilizer use within Tier 2 reporting would support more accurate GHG inventories and enable more targeted and effective mitigation planning.

The emission estimates for maize, calculated using published emission factors, revealed substantial variation depending on the emission factor applied (Table 4). For instance, the lowest published emission factor of 0.005 kg N_2O-N per kg N is notably lower than the IPCC default value of 0.01. Several studies have suggested that global emission factors for both organic and synthetic fertilizer inputs may overestimate GHG emissions under local conditions. These findings underscore the importance of not only improving activity data but also using country-specific emission factors that better reflect local climate, soil, and management conditions to enhance the accuracy of emission estimates.

Estimated emissions per hectare from manure application were higher for some crops—such as coffee, tea, maize, and millets—compared to emissions from synthetic fertilizers (Table 5). This highlights the importance of including manure-related emissions in the national GHG inventory. Currently, there is no national dataset on manure production in Kenya.

The current inventory estimates emissions from manure application based on livestock population data, assuming a fixed percentage of the manure is applied to cropland. However, our results show variability in manure application across different crop types, with some crops contributing significantly more to emissions than others. This suggests that crop-specific data are important for improving the accuracy of manure emission estimates.

Additionally, emissions from manure application were generally higher on crops grown on smaller land parcels, indicating that farmers with limited land may apply higher nitrogen inputs per hectare. It is important to note, however, that the manure-related emission estimates presented here are subject to uncertainty. Farmer-reported quantities were converted into kilograms per hectare using standard conversion factors from previous studies. A nitrogen content of 1.36% was assumed for all manure, with the assumption that it was applied in dry matter form. Manure characteristics—including nitrogen content and moisture level—can vary significantly depending on the source and handling practices. Therefore, further validation of both conversion factors and nitrogen content assumptions is needed to improve the robustness of these estimates.

The total emissions from the burning of maize residues were relatively low (Table 6). This is largely attributed to the fact that most farmers repurpose crop residues as livestock feed rather than burning them. However, further data collection on crop residue burning is necessary to validate the assumptions currently used in the national inventory and to better understand the extent and impact of this practice.

Table 3: Direct, indirect, and total emissions (kg CO_2 eq.) and total emissions per hectare (kg CO_2 eq. ha^{-1}) from fertilizer application for crops included in the inventory, estimated using two approaches: the Tier 1 method used by MOALD and the Improved Tier 1 method based on pilot farm data. See section 2.4.1 for detailed explanation on the differences in the areas in the two methodologies.

		Tier 1 (current MOALD approach)					Tier 1 Improved				
County	**Crop**	**Area (ha)**	**Direct emissions (kg CO_2 eq.)**	**Indirect emissions (kg CO_2 eq.)**	**Total Emissions (kg CO_2 eq.)**	**Total emissions (kg CO_2 eq. ha^{-1})**	**Area (ha)**	**Direct emissions (kg CO_2 eq.)**	**Indirect emissions (kg CO_2 eq.)**	**Total emissions (kg CO2 eq.)**	**Total emissions (kg CO_2 eq. ha^{-1})**
Baringo	Beans	8.70	505.25	226.97	732.22	84.15	8.3	617.22	200.6	817.82	98.58
	Coffee	1.01	117.03	52.57	169.60	167.63	0.61	77.22	25.1	102.32	168.55
	Maize	21.65	5531.87	2485.04	8016.91	740.54	15.68	1778.2	577.92	2356.12	150.24
	Millets	5.67	1447.59	650.29	2097.88	740.54	1.21	53.62	17.43	71.05	58.52
	Sorghum	3.24	827.20	371.59	1198.79	740.54	1.42	121.19	39.39	160.58	113.37
Makueni	Beans	4.77	276.71	124.30	401.02	84.15	2.71	112.67	36.62	149.28	55.16
	Coffee	0.42	48.78	21.91	70.69	167.63	0.78	28.8	9.36	38.16	49.19
	Maize	28.02	7157.83	3215.46	10373.29	740.54	14.77	729.3	237.02	966.32	65.42
	Potatoes	0.15176	38.775	17.4185	56.1933	370.27	0.15	1.31	0.43	1.73	11.42
	Sorghum	11.43	2921.04	1312.19	4233.23	740.54	1.21	44.72	14.54	59.26	48.81
Murang'a	Beans	3.41	197.87	88.89	286.76	84.15	2.17	41.17	13.38	54.55	25.19
	Coffee	3.41	394.61	177.27	571.88	167.63	3.32	100.73	32.74	133.47	40.22
	Maize	12.57	3211.59	1442.72	4654.31	740.54	10.48	366.52	119.12	485.65	46.35
	Sorghum	0.34	86.86	39.02	125.87	740.54	0.02	1.67	0.54	2.22	91.3
	Tea	0.05	6.09	2.73	8.82	167.63	0.05	1.39	0.45	1.85	35.11
		Tier 1 (current MOALD approach)					Tier 1 Improved				

County	Crop	Area (ha)	Direct emissions (kg CO_2 eq.)	Indirect emissions (kg CO_2 eq.)	Total Emissions (kg CO_2 eq.)	Total emissions (kg CO_2 eq. ha^{-1})	Area (ha)	Direct emissions (kg CO_2 eq.)	Indirect emissions (kg CO_2 eq.)	Total emissions (kg CO2 eq.)	Total emissions (kg CO_2 eq. ha^{-1})
Nyamira	Beans	3.67	213.38	95.85	309.23	84.15	3.57	90.15	29.3	119.45	33.46
	Maize	12.57	3211.59	1442.72	4654.31	740.54	6.64	137.53	44.7	182.23	27.46
	Millets	1.08	277.11	124.48	401.59	740.54	0.35	3.98	1.29	5.28	15.17
	Tea	3.24	374.95	168.44	543.39	167.63	1.98	222.01	72.15	294.16	148.64
Taita Taveta	Beans	15.68	910.62	409.07	1319.69	84.15	7.28	538.4	174.98	713.37	97.93
	Maize	12.57	3211.59	1442.72	4654.31	740.54	19.93	1922.99	624.97	2547.97	127.84
	Millets	0.20	51.70	23.22	74.92	740.54					
	Rice	25.09	6410.77	2879.86	9290.63	740.54	7.89	420.42	136.64	557.06	70.59
	Sorghum	2.43	620.40	278.70	899.09	740.54	0.2	9.65	3.14	12.79	63.21

Table 4: Direct N_2O emissions for fertilizer application in maize in the pilot counties estimated using the maximum and minimum available emission factors in published literature in Kenya.

		Direct N_2O Emissions (kg CO_2 eq)		Direct N_2O Emissions (kg CO_2 eq. ha^{-1})	
County	**Area (ha)**	**EF = 0.005**	**EF = 0.014**	**EF = 0.005**	**EF = 0.014**
Baringo	15.68	889.1	2489.49	56.7	158.75
Murang'a	10.48	183.26	513.13	17.49	48.97
Nyamira	6.64	68.76	192.54	10.36	29.01
Taita Taveta	19.93	961.5	2692.19	48.24	135.07
Makueni	14.77	364.65	1021.02	24.69	69.12

Table 5: Direct, indirect, and total emissions (kg CO_2 eq.) and total emissions per hectare (kg CO_2 eq. ha^{-1}) from manure application for crops included in the inventory.

County	Crop	Area (ha)	Direct (kg CO_2 eq.)	Indirect (kg CO_2 eq.)	Emissions (kg CO_2 eq.)	Emissions (kg CO_2 eq. ha-1)
Baringo	Beans	4.45	256.71	109.1	365.82	82.17
	Coffee	0.4	11.67	4.96	16.63	41.09
	Maize	8.8	507.59	215.73	723.32	82.17
	Millets	1.01	175.03	74.39	249.42	246.52
	Sorghum	1.01	233.38	99.18	332.56	328.7
Murang'a	Beans	2.46	230.2	97.83	328.03	133.53
	Coffee	3.41	1205.01	512.13	1717.14	503.32
	Maize	6.04	609.75	259.15	868.9	143.81
	Sorghum	0.12	5.41	2.3	7.72	65.74
	Tea	0.05	15.17	6.45	21.62	410.87
Nyamira	Beans	2.65	57.24	24.33	81.56	30.82
	Maize	3.83	82.79	35.19	117.98	30.82
	Millets	0.31	11.64	4.95	16.59	53.93
	Tea	1.58	34.13	14.51	48.64	30.82
Taita Taveta	Beans	3.34	141.99	60.35	202.34	60.6
	Maize	11.53	665.12	282.68	947.8	82.17
Makueni	Beans	4.46	514.59	218.7	733.3	164.35
	Coffee	0.42	25.53	10.85	36.39	86.28
	Maize	14.01	2423.32	1029.91	3453.23	246.52
	Potatoes	0.15	2.41	1.02	3.43	22.6

Table 6: Estimated emissions from burning of maize residues in the five counties

County	Area (ha)	Burnt biomass t ha^{-1}	CH_4 emissions (kg CO_2 eq.)	N_2O emissions (kg CO_2 eq.)	Total emissions (kg CO_2 eq. ha^{-1})
Baringo	0.809	0.479	0.033	0.015	0.073
Makueni	0.577	1.791	0.043	0.020	0.820
Murang'a	1.336	3.622	0.120	0.056	1.015
Taita Taveta	5.868	9.570	0.815	0.378	0.966

2.6 Next steps for tool scaling and transition to Tier 2

To ensure the sustainability and nationwide scale-up of the GHG activity data collection tool, it is essential to integrate it within existing national agricultural data systems. The Ministry of Agriculture and Livestock Development (MOALD) has developed the Kenya Integrated Agriculture Management Information System (KIAMIS), a digital platform designed to support evidence-based decision-making, improve service delivery to farmers, and enhance the flow of information among stakeholders at both county and national levels. Integrating the GHG tool into KIAMIS presents a valuable opportunity to institutionalize emissions data collection within the country's broader agricultural information infrastructure. Such integration would enable centralized and secure data storage, real-time access to data by relevant stakeholders, improved harmonization of information across agricultural programs, and enhanced data accuracy while reducing duplication of efforts. This would ultimately support efficient monitoring and reporting of agriculture-related greenhouse gas emissions and strengthen Kenya's Measurement, Reporting, and Verification (MRV) systems, facilitating the country's transition to Tier 2 GHG reporting in line with IPCC guidelines.

In the pilot phase, the tool was used to estimate emissions primarily from nitrogen inputs (fertilizer and manure) and maize residue burning. These areas were selected to demonstrate how the tool can improve emissions reporting. While the current analysis focused on these factors, the tool also collected data on other important agricultural practices such as tillage, agroforestry, and lime application. These additional data points were not fully utilized in the pilot but can provide valuable insights in future assessments. Such data is needed for Tier 2 estimation, providing a more detailed understanding of emissions from different crop types and management practices. It could help address emissions related to land use changes, enhance soil carbon sequestration, and support more targeted GHG mitigation strategies across various agro-ecological conditions.

The successful national rollout of the tool requires robust training and capacity-building efforts targeting key actors, including county agricultural officers, extension agents, enumerators, and farmers. These stakeholders need a thorough understanding of the tool's purpose, structure, and operational requirements, including the use of digital data collection platforms such as SurveyCTO, procedures for ensuring data quality and completeness, and strategies for proper data submission and troubleshooting. Additionally, they must be equipped with knowledge on the fundamentals of greenhouse gas emissions in agriculture, IPCC reporting methods, relevant national policies, and best practices for inventory data management and secure digital storage. Strengthening ICT infrastructure and ensuring that stakeholders have the technical skills and tools needed for long-term, secure data access and availability is essential for ensuring timely and accurate reporting.

At the same time, addressing key data and methodological gaps is necessary to support the transition to Tier 2 reporting. Currently, national inventories rely on generalized emission factors that do not fully reflect Kenya's diverse agro-ecological conditions. Evidence from the pilot shows that emissions vary significantly by crop type and management practice, particularly in relation to manure and fertilizer application. This highlights the need to develop localized emission factors that are more representative of actual conditions on Kenyan farms. Achieving this will require identifying and supporting national research institutions and universities capable of conducting field-based GHG measurements, establishing standardized protocols for emissions testing across representative regions, and fostering collaboration between the Ministry, climate research organizations, and international experts. Developing a robust, country-specific database of emission factors will contribute to more accurate and transparent reporting and help inform more realistic and effective mitigation actions in the agricultural sector.

3. Integration of the GHG activity data into CSART

3.1 CSART Adaptation Tool

The Climate Smart Agriculture Reporting Tool (CSART) is an innovative digital platform designed to operationalize Kenya's Climate-Smart Agriculture (CSA) Monitoring and Evaluation (M&E) Framework (MoAFLC, 2021). This framework is essential for guiding the agriculture sector toward low-carbon, climate-resilient development by defining key indicators, data requirements, and reporting guidelines. CSART enhances this framework by offering a streamlined, transparent, and harmonized system for tracking climate action in agriculture. As a web-based, user-friendly tool, it enables stakeholders—including government agencies, private sector entities, research institutions, and community-based organizations—to capture, track, and analyse CSA intervention data. By consolidating information in real-time, CSART facilitates greenhouse gas (GHG) emissions tracking, adaptation strategy assessment, and progress evaluation toward Kenya's CSA targets. Additionally, its integration of climate action data into a single, cohesive system ensures transparency and alignment with Monitoring, Reporting, and Verification (MRV) requirements.

CSART provides a structured process for data collection, validation, aggregation, and reporting, ensuring compliance with the Kenya CSA Implementation Framework (KCSAIF) 2018–2027. The reporting process is centred on ongoing climate-smart programs and projects, where adaptation measures are actively tracked. Within these initiatives, relevant data collection forms and performance indicators—aligned with KCSAIF—are established to ensure consistent progress monitoring. These indicators employ predefined aggregation rules, such as summing, counting, or averaging, to compile reported data systematically. The platform also enables the registration of administrative locations, including counties, sub-counties, and wards, ensuring multi-level data capture. Users, such as county officials and field personnel, are assigned roles as data reporters or reviewers. During reporting periods—whether monthly, quarterly, or annually—reporters input and submit data for validation. Reviewers then assess submissions, approving them for aggregation or requesting corrections. Validated data is systematically aggregated from local to national levels, providing a comprehensive and transparent record of Kenya's CSA adaptation efforts.

By centralizing climate action reporting, CSART equips decision-makers at national and county levels with reliable data to inform adaptation planning, strengthen policy interventions, and support Kenya's adaptation transparency commitments under international climate agreements.

3.2 Activity data Integration into CSART

Since many climate-smart adaptation and mitigation measures are interconnected, a unified platform simplifies reporting and tracking for the Ministry of Agriculture. Unlike CSART, which focuses on structured, indicator-based reporting with pre-aggregated project data provided by stakeholders, the GHG Activity Data Collection Tool is specifically designed for field data collection. This tool relies on routine data collection by enumerators, who could be extension workers or officers, gathering information directly from farmers. As part of this project, we integrated the activity data collected through this tool into CSART as a dedicated module, ensuring that GHG reporting aligns seamlessly with Kenya's broader CSA monitoring framework.

To integrate GHG activity data reporting within CSART, we developed a GHG activity data module by linking the SurveyCTO-based GHG Data Collection Tool with CSART's existing framework (Table A5). The integration process followed a structured approach, starting with configuring SurveyCTO for automated data retrieval and creating a dedicated user account with API access to facilitate seamless data transfer. CSART was then adapted to manage GHG data by establishing a dedicated subsection, incorporating Kenya's administrative units, defining user roles, and designing a data workflow for validation and aggregation. To enable automated data integration, we developed modules for fetching, mapping, transforming, and storing survey data within CSART's database. The integration was tested using datasets from five pilot counties, validating data accuracy, workflow transitions, and indicator calculations. The result was a fully operational GHG activity data module within CSART, significantly enhancing Kenya's capacity for transparent, efficient, and data-driven climate reporting.

3.3 Opportunities for MRV, NDC Tracking, and Updating

The Monitoring, Reporting, and Verification (MRV) system for greenhouse gas (GHG) emissions in Kenya's crop sub-sector is not yet fully established within the Ministry of Agriculture. However, the integration of GHG activity data reporting into CSART offers a structured and scalable system through which GHG activity data can be collected from ward, sub-county, and county levels. By incorporating a dedicated GHG activity data module into CSART, the platform enables field-based data collection on key emission sources—such as fertilizer use, manure application, perennial crop integration, tillage practices, and crop residue management—which are essential for compiling a robust national GHG inventory.

The integration of the GHG module into CSART is further supported by a policy analysis conducted as part of this initiative. This analysis reviewed Kenya's agriculture, climate, and environmental policies and assessed their alignment with national GHG inventory needs (Ndetu et. al, 2024). It revealed a significant gap between policy objectives and the availability of reliable, field-level data to support implementation and reporting. Most existing policies are not well anchored in empirical data from farming systems, limiting their effectiveness in informing national greenhouse gas inventories or tracking mitigation outcomes. The analysis highlighted the need for better integration of real-time, localized activity data into planning and reporting processes to ensure that policy decisions are based on actual land management practices and reflect the diversity of Kenyan farming systems. Embedding tools like CSART into Kenya's institutional frameworks provides a pathway to close this data-policy gap and improve the accuracy and transparency of climate action reporting.

Kenya aims to reduce its GHG emissions by 32% by 2030 relative to the business-as-usual scenario. The country's Nationally Determined Contribution (NDC) integrates Climate-Smart Agriculture (CSA) to meet both mitigation and adaptation goals. The CSA Strategy (2017–2026) aims to enhance agricultural productivity, build resilience, and reduce emissions—specifically targeting a reduction in agricultural emissions from 39.8 $MtCO_2e$ to 32.2 $MtCO_2e$ by 2026. Key mitigation actions include promoting agroforestry (3.99 $MtCO_2e$ abatement by 2030) and expanding sustainable land management practices such as conservation tillage (0.83 $MtCO_2e$ reduction) (Government of Kenya, 2020).

Tracking progress toward these targets requires a robust MRV system capable of generating reliable, spatially explicit, and periodically updated datasets on land management practices. The GHG module integrated into CSART enables the systematic collection of such data and offers strong potential to support MRV across multiple reporting cycles. The tool provides detailed insights into the adoption of CSA practices and facilitates aggregation at multiple governance levels, which is essential for transparent monitoring, evaluation, and updating of Kenya's NDC.

In addition, CSART offers flexible reporting periods and the ability to track historical data—a functionality currently limited within the Ministry. The platform allows GHG activity data to be collected, stored, and retrieved across multiple reporting cycles, ensuring continuity and accessibility of past datasets for inventory compilation and trend analysis. The developed CSART platform can support Kenya's long-term climate reporting capabilities by enabling evidence-based planning and more effective CSA interventions.

To further improve the functionality of the GHG module within CSART, the integration of GHG emission calculators based on IPCC methodologies could be implemented. These calculators would automatically estimate emissions from different cropland categories using the aggregated data, simplifying and improving the accuracy of the reporting process. Moving toward a Tier 2 approach—requiring country-specific emission factors—would involve embedding more detailed parameters, such as soil properties, land use history, and regional climate data. This enhancement would allow CSART to deliver more precise emission estimates reflective of local conditions and practices, ultimately contributing to more transparent and accurate national GHG inventories and climate action reporting.

3.4 Institutional Arrangements

Effective implementation of GHG activity data collection and management requires a coordinated effort led by the Ministry of Agriculture's Climate Change Unit (MoALF CCU). To ensure efficiency and avoid duplication, the institutional arrangements for GHG inventory data should align with existing data collection systems—particularly the climate-smart agriculture reporting tool (CSART).

To operationalize the data collection tool, MoALF CCU must work closely with county departments of agriculture to integrate the tool into existing systems. Ward-level officers should be fully equipped and trained to systematically collect activity data from farmers.

Unlike adaptation data, inventory data requires not only validation but also compilation and modeling to produce a comprehensive GHG inventory report. This process demands both activity data and crop- or area-specific emission factors. A dedicated team of compilers and modelers—drawn from CCUs at both national and county levels and supported by research institutions with modeling expertise—will be essential. These institutions can provide scientifically derived emission factors.

The climate-smart agriculture multi-stakeholder platform (CSA-MSP), which serves as the coordination mechanism for CSART under the CSA M&E framework, should be used to identify members of this team. The team should have access to the collected data and the mandate to validate it prior to modeling. Once the inventory report is generated, it must be validated by the CCUs and CSA-MSPs at both levels of government before being submitted to the national focal point by the MoALF CCU coordinator.

Data collection begins at the ward level, where officers and extension staff collect field-level activity data directly from farmers using the designated tool. This process will require adequate resourcing, including the definition of timelines and survey frequency.

Although the CSART platform allows for automated aggregation of collected data, the CCU must coordinate with counties to assign administrators responsible for validating and approving ward-level data. Establishing a robust coordination mechanism among the MoALF CCU, county governments, ward officers, and other stakeholders is critical for ensuring smooth data flow, quality control, and capacity building. This structure will facilitate seamless data aggregation from the ward to national level, strengthening Kenya's agricultural MRV system and advancing national climate action.

4. Steps forward for Improving the GHG Inventory

The pilot phase of GHG data collection successfully demonstrated the potential of collecting disaggregated, farm-level activity data to improve the accuracy of Kenya's greenhouse gas (GHG) inventories in the agriculture sector. Data collected during the survey focused on fertilizer use, manure application, crop types, and crop residue management practices, which are critical for Tier 2 GHG reporting. These data provide more granular insights compared to the national averages used in the current inventory, highlighting the need for localized emission factors and activity data.

Key findings from the pilot include the importance of transitioning from Tier 1 to Tier 2 reporting to capture variability in farming practices and improve emission estimates. The integration of the developed GHG data collection tool into the Climate Smart Agriculture Reporting Tool (CSART) was a significant step forward in streamlining data management and ensuring that data can be efficiently captured, stored, and accessed across counties. This integration lays the groundwork for future operationalization, ensuring that the tool becomes a permanent part of Kenya's agricultural data management system.

To scale this work and move towards a nationwide implementation, it is critical to invest in capacity building. Initial efforts should focus on training agricultural officers, enumerators, and farmers in additional counties on how to effectively use the tool and manage data. As GHG data reporting becomes a regular process, adequate funding is essential not only to support this initial capacity-building effort but also to ensure the long-term sustainability of the system. More resources will be needed for scaling purposes, including expanding tool usage, enhancing data collection infrastructure, and addressing gaps in emission factor development.

The Ministry of Agriculture and Livestock Development, in collaboration with key stakeholders—including KALRO, NEMA, and other development partners—should focus on operationalizing the tool and continuing the integration with CSART. This process will enable real-time reporting of GHG emissions and ensure that Kenya is equipped to meet its climate reporting obligations while also enhancing the effectiveness of mitigation actions.

In summary, the following sequential steps are proposed to strengthen Kenya's greenhouse gas (GHG) inventory in the crop sub-sector:

1. **Scale up tool use and train additional counties**
   Expand the use of the GHG data collection tool to more counties and train agricultural officers and enumerators to ensure consistent, high-quality data collection.

2. **Institutionalize the GHG Data Tool within CSART**
   Ensure the Ministry of Agriculture adopts and uses the integrated GHG module in CSART as part of routine data management and reporting.

3. **Transition to tier 2 GHG reporting**
   Shift from Tier 1 to Tier 2 GHG estimates using disaggregated, farm-level data to improve accuracy and regional representation.

4. **Secure sustainable funding and infrastructure**
   Mobilize financial resources and invest in digital infrastructure to support long-term operation and expansion of the reporting system.

5. **Develop and apply local emission factors**
   Collaborate with KALRO and other research and academic institutions to create and validate region-specific emission factors using collected field data.

6. **Establish routine data collection and historical tracking**
   Institutionalize regular data collection cycles and enable CSART to track and analyse historical emissions data.

7. **Foster multi-stakeholder coordination**
   Strengthen collaboration among government agencies, counties, and development partners to align reporting with Kenya's NDCs and MRV requirements.

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Annexes

Table A1: The number of farmers growing each crop, the total cropland area (ha) under different fertilizers, and the minimum, median, and maximum fertilizer application rates (kg/ha). The selected are only those that are currently included in the inventory.

County	Crop	Fertilizer type	No. of farmers	Area	Minimum	Median	Maximum
Baringo	Beans	CAN	4	1.01	61.78	92.66	247.1
		DAP	10	3.84	61.78	123.55	123.55
		NPK	9	3.44	61.78	98.84	247.1
	Coffee	CAN	1	0.2	247.1	247.1	247.1
		NPK	1	0.4	123.55	123.55	123.55
	Maize	CAN	11	5.26	61.78	123.55	247.1
		DAP	11	4.86	61.78	123.55	185.33
		NPK	9	5.56	61.78	247.1	247.1
	Millets	DAP	3	1.01	61.78	61.78	123.55
		NPK	1	0.2	61.78	61.78	61.78
	Sorghum	DAP	4	1.21	61.78	123.55	123.55
		NPK	1	0.2	61.78	61.78	61.78
Murang'a	Beans	CAN	11	0.53	2.47	24.71	247.1
		DAP	6	0.71	4.94	17.3	123.55
		NPK	18	0.92	2.47	43.24	247.1
		Urea	1	0	4.94	4.94	4.94
	Coffee	CAN	5	0.59	4.94	61.78	74.13
		DAP	1	0.04	24.71	24.71	24.71
		NPK	19	2.25	4.94	61.78	185.33
		Urea	3	0.45	4.94	24.71	123.55
	Maize	CAN	34	4.48	2.47	49.42	247.1
		DAP	18	2.13	2.47	24.71	247.1
		NPK	30	3.31	12.36	55.6	247.1
		Urea	5	0.56	4.94	14.83	123.55
	Sorghum	CAN	1	0.02	61.78	61.78	61.78
	Tea	NPK	1	0.05	61.78	61.78	61.78
Nyamira	Beans	CAN	2	0.2	98.84	111.2	123.55
		DAP	28	3.13	7.41	24.71	123.55
		NPK	1	0.2	61.78	61.78	61.78
		Urea	2	0.04	7.41	16.06	24.71
	Maize	CAN	16	2	7.41	24.71	123.55
		DAP	35	4.31	12.36	24.71	123.55
		Urea	3	0.32	24.71	24.71	61.78

County	Crop	Fertilizer type	No. of farmers	Area	Minimum	Median	Maximum
	Millets	DAP	5	0.35	7.41	14.83	61.78
	Tea	CAN	3	0.53	123.55	247.1	741.31
		NPK	9	1.45	24.71	123.55	494.21
Taita Taveta	Beans	CAN	8	2.12	61.78	123.55	123.55
		DAP	9	2.12	29.65	123.55	123.55
		NPK	3	0.81	61.78	123.55	123.55
		Urea	8	2.23	123.55	123.55	123.55
	Maize	CAN	17	7.59	61.78	123.55	494.21
		DAP	18	6.78	32.12	123.55	308.88
		NPK	8	4.35	61.78	123.55	1111.97
		Urea	4	1.21	61.78	123.55	123.55
	Rice	CAN	2	0.81	123.55	123.55	123.55
		DAP	4	1.62	123.55	247.1	494.21
		Urea	11	5.46	123.55	123.55	494.21
	Sorghum	DAP	1	0.2	61.78	61.78	61.78
Makueni	Beans	CAN	8	1.14	7.41	39.54	123.55
		DAP	7	0.99	4.94	61.78	123.55
		NPK	5	0.58	49.42	61.78	148.26
	Coffee	CAN	1	0.2	61.78	61.78	61.78
		DAP	2	0.3	24.71	43.24	61.78
		NPK	2	0.27	19.77	40.77	61.78
	Maize	CAN	16	6.1	4.94	61.78	247.1
		DAP	7	2.1	12.36	61.78	247.1
		NPK	15	6.58	7.41	74.13	185.33
	Potatoes	DAP	1	0.1	9.88	9.88	9.88
		NPK	1	0.05	24.71	24.71	24.71

Table A2: The number of farmers growing each crop and applying farmyard manure, the total cropland area (ha) under manure, and the minimum, median, and maximum manure application rates (kg/ha).

County	Crop	No. of farmers	Area	Minimum	Median	Maximum
Baringo	Beans	12	4.45	80	400	800
	Coffee	1	0.4	200	200	200
	Maize	18	8.8	40	400	1600
	Millets	3	1.01	400	1200	10000
	Sorghum	3	1.01	400	1600	10000
County	**Crop**	**No. of farmers**	**Area**	**Minimum**	**Median**	**Maximum**
Murang'a	Beans	21	2.46	70	650	7000
	Coffee	26	3.41	70	2450	14000
	Maize	37	6.04	140	700	7000
	Sorghum	4	0.12	200	320	2000
	Tea	1	0.05	2000	2000	2000
Nyamira	Beans	26	2.65	40	150	400
	Maize	32	3.83	30	150	1200
	Millets	4	0.31	60	262.5	600
	Tea	6	1.58	30	150	200
Taita Taveta	Beans	10	3.34	105	295	4000
	Maize	26	11.53	75	400	15000
Makueni	Beans	27	4.46	200	800	10000
	Coffee	4	0.42	350	420	10000
	Maize	42	14.01	75	1200	30000
	Potatoes	2	0.15	80	110	140
	Potatoes	2	0.15	80	110	140

Table A3: The top ten crop grown in each county based on their area.

Baringo	No. of farmers	Makueni	No. of farmers	Murang'a	No. of farmers	Nyamira	No. of farmers	Taita Taveta	No. of farmers
Beans	22	Maize	42	Maize	38	Maize	39	Maize	63
Maize	21	Green gram	30	Bananas	29	Beans	36	Beans	58
Millets	10	Beans	29	Beans	26	Managu	29	Green gram	34
Sorghum	6	Cowpeas	29	Coffee	26	Kales	24	Rice	26
Coffee	4	Pigeon pea	24	Avocado	22	Tea	19	Bananas	21
Mangoes	4	Sorghum	22	Nappier grass	21	Bananas	16	Cowpeas	17
Avocado	3	Fresh bean	13	Mangoes	18	Millets	10	Pigeon pea	12
Boma Rhodes	3	Kales	12	Kales	13	Onions	8	Cassava	5
Cabbage	2	Mangoes	11	Sweet potatoes	7	Cabbage	6	Sorghum	5
Kales	2	Bananas	10	Cassava	6	Nappier grass	2	Kales	4

Table A4: The survey question used to structure the GHG data collection tool for Kenya crop subsector. The online version of the tool is available via Survey CTO[2].

Category	Question	Choice
Enumerator details	Enumerator's name	
Farmer details and location	Name of County	
	Name of Subcounty	
	Name of ward	
	Name of village	
	Name of the respondent farmer	
	Under which age category does the respondent lie?	18-25yrs, 26-34yrs, 35-44yrs, 45-54yrs, 55-64yr, 65-74yrs, 75yrs and above
	What is the total size of the land used for cultivation?	
Monocrop Information	Name the five major top crops grown in your farm (grown as monocrops)?	List of all crops found in Kenya, e.g., maize, beans, tea, coffee, potatoes, pigeon pea etc. **Note**: Other included in the responses and if crop is missing from list enumerator fills manually
	What is the area under each crop?	**Note**: Enumerator fills manually the area under each of the five major crops and their yield .
	What the harvested yield from each crop?	
Intercropping information	Do you practise intercropping in your farm?	Yes, No
	Which crops do you intercrop?	List of the common intercrops in Kenya (e.g., maize - bean, maize - pigeon pea, coffee-maize etc.)
	What is the area (acres) under intercrop?	Note: Enumerator fills manually the area in acres for each of the selected intercrops and their yield.
	What the harvested yield from each crop	
Livestock information	Do you keep livestock in your farm?	Yes, No
	Which livestock do you keep?	List of animals and poultry found in Kenya, cow, sheep, goat, pigs, rabbits, donkeys etc.
	How many of each type do you have?	Enumerators fill the number according to respondent response.
	How many Kgs of manure do you collect from each livestock?	Enumerators fill the number according to respondent response.

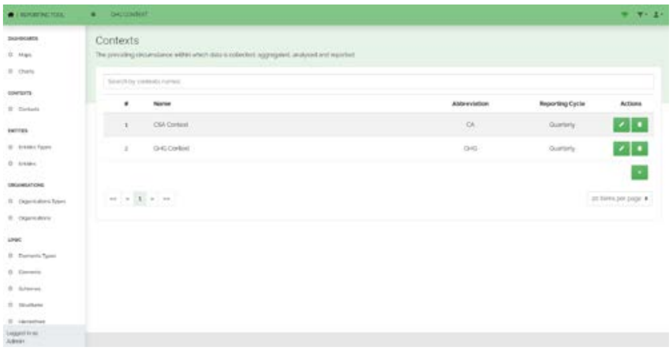
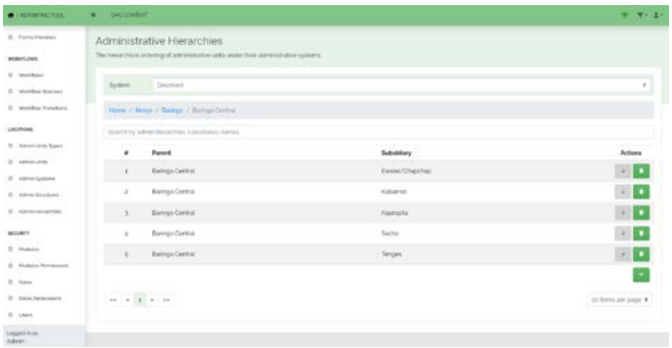
2 https://mflghg.surveycto.com/collect/Assesment_tool?caseid=

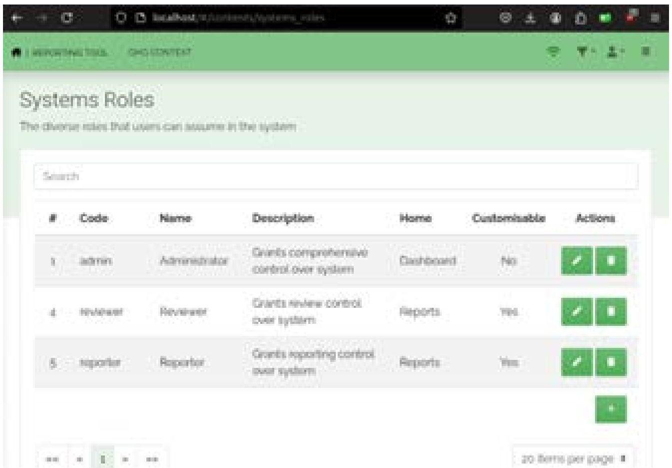
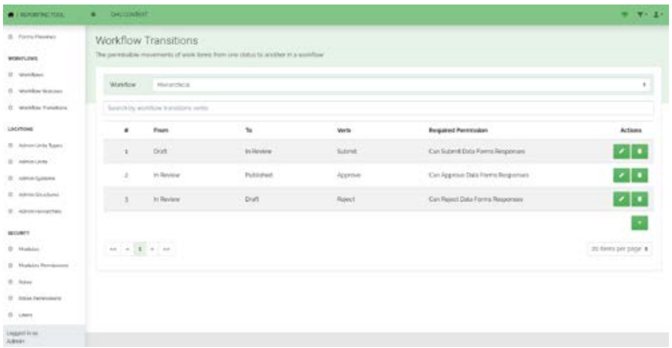
Category	Question	Choice
Manure information	Do you use manure in your farms?	Yes, No
	What is the type/source of your manure?	Farmyard manure, Compost, Green manure
	In which crops do you apply manure?	Selection based on the list of crops that the farmer had mentioned initially.
	What do you use to carry manure in your farm?	Animal cart, tractor, bucket, wheelbarrow, sack, and lorry. The conversion rates to Kgs were 200, 15, 3000, 2000, 70, and 40 for animal cart, bucket, lorry, tractor, sack and wheelbarrow respectively. **Note**: Conversion rates aren't automated, the factors need to be applied manually to convert to correct units. Future validation of the values will be needed.
	Please state the amount of manure applied in each crop?	Enter manually
	How often do you apply manure in each crop mentioned?	Seasonally (every season), Annually (once a year), Other (Specify)
	Do you apply manure in intercrop?	
	In which intercrop do you apply manure?	
	What do you use to carry manure in your farm?	
	How often do you apply manure in intercrop?	Seasonally (every season), Annually (once a year), Other (Specify)
	Fertilizer management crops	
Fertilizer information	Do you use inorganic fertilizer?	Yes, No
	Which crop do you apply fertilizer?	Note: to be selected from the list of crops that the farmer say they grow
	State the type of inorganic fertilizer you applied on each crop.	NPK, DAP, Urea, TSP, SA, CAN, Other (Specify)
	What is the amount of each fertilizer (kgs0 applied in each crop?	
	From the selected intercrop, which do you apply fertilizer?	
	State the type of fertilizer applied in intercrop grown in your farm?	NPK, DAP, Urea, TSP, SA, CAN, Other (Specify)
	What the amount of each fertilizer (in kgs) applied in the intercrop?	
	How often have you been applying fertilizer in intercrop?	Seasonally (every season), Annually (once a year), Other (Specify)

Category	Question	Choice
Lime information	Do you use lime in your farm?	Yes, No
	What area of land do you apply lime on?	
	How often do you apply lime in your farm?	Seasonally (every season), Annually (once a year), Other (Specify)
	Which crops do you apply lime from the selected options?	
	State the amount (kgs) of lime applied in mentioned crops?	
Tillage information	What type of tillage do you practice in your land.	Full Tillage, Reduced Tillage, Zero Tillage
	What type of tillage do you practice in each crop mentioned above?	Full Tillage, Reduced Tillage, Zero Tillage
Crop harvest information	How do you manage crop residues in your farm?	Choose from burning, plough - in, mulching , livestock feed, Other (Specify)
	What percentage of residues do you utilize in each management mentioned above?	
Cover crop information	Do you use cover crops?	Yes, No
	What type of cover crops do you use?	Alfalfa, Cowpeas, Fava Beans, Soyabeans, Pea, Desmodium, Dolichos, Pumpkins, Sweet potatoes, Brassicas, mucuna, Others (Specify)
	On what proportion of your cropping area do you use cover crops?	
Tree information	Have you planted trees in your farm?	Ye, No
	What is the purpose of the trees planted in your farm?	Fruit Trees, Timber Tree, Fodder tree, Medicinal Trees
	What the average age of the trees in your farm?	Young (0-5), Mid (6-20), Old (> 20)
	How many trees are in each age group in your farm?	
Mechanization information	Do you use agricultural machinery/ equipment on your farm?	Yes, No
	Do you own any agricultural equipment?	Yes, No
	Which machines do you own?	Select from a list; e.g., Tractor, Cultivators and Tillers, Planters and seeders, Manure spreaders e.t.c
	Which are the agricultural machine used in your farm?	
	What the size of land under mechanization by each equipment mentioned?	

Category	Question	Choice
Rice cultivation	What type of management is used for rice cultivation in your farm?	Upland, Intermittent, Rainfed
	What is the duration of the growth of the rice in months?	
	What is the area under the rice in your land?	
	What type of fertilizer do you use in your rice farm?	
	How many (Kgs) of each fertilizer do you use in your rice farm?	NPK, DAP, Urea, TSP, SA, CAN, Other (Specify)
	Do you apply Farm yard manure in your rice?	Yes, No
	If yes, how much	
Location	Field GPS	Collected when closing interview

Table A5: Screen shots showing the integration of the GHG activity data collected through survey CTO in the CSART tool. The integration provides summarized data that can be used in estimating emissions in the inventory and to guide NDC targets and tracking.

Description	Visual Reference
A "GHG" subsection was added to CSART, ready to store and manage activity data.	
All counties, sub-counties, and wards were added, ensuring accurate mapping of pilot data. This can also be extended to include all the 47 counties.	

Description	Visual Reference
Administrator, Reporter, and Reviewer roles were defined, each with appropriate permissions.	
Accounts for each role were established to facilitate testing and demonstration.	
Enabled structured review processes for manual entries or automatically integrated data.	

Description	Visual Reference
A form mirroring SurveyCTO fields (e.g., "Total land size under cultivation") was set up in CSART.	
Indicators were linked to form fields, specifying summing, averaging, or counting operations.	

Photo: © Alliance of Bioversity & CIAT

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