Title of the Proposal:

Leveraging AI for near real-time cattle counting and Farming system indexing using UAV Videos and images for estimation of GHG emissions (LAIRG)

Call ID: IDRC-SIDA-RUFORUM/WASCAL/A2063-IRG/2022

Principal Investigator: **Assoc. Prof. Eng. Isa Kabenge**
Makerere University, P.O. Box 7062, Kampala (Uganda)
Email address: isakabenge@gmail.com
Telephone (WhatsApp): +256-772-377-172

Names of participating researchers

Assoc. Prof. Anthony Gidudu
Makerere University, P.O. Box 7062, Kampala (Uganda)
Email address: anthony.gidudu@gmail.com

Emmanuel Omia
Institution: Makerere University, P.O. Box 7062, Kampala (Uganda)
Email: deusviam@gmail.com

Evet Naturinda
Institution: Makerere University, P.O. Box 7062, Kampala (Uganda)
Email: evet.naturinda@gmail.com

Fortunate Kemigyisha
Institution: Makerere University, P.O. Box 7062, Kampala (Uganda)
Email: kemfortie@gmail.com

Project duration: (18 months);

Total Budget requested in US$: (US$ 60,000).

ii) Summary (500 words maximum)

Rationale: Globally, 18% of the annual worldwide GHG emissions are attributable to livestock production (FAO, 2006). Estimation of GHGs is pivotal in the efforts to reduce GHGs from the livestock sector to continue supporting economic services in a sustainable way (Kipling *et al*., 2016). Recent advancements in using Remote Sensing and Machine learning to automate data collection processes promise to achieve reliable results for GHG emissions estimation. These methods, however, haven't been sufficiently applied in Africa. None the less, application of Artificial Intelligence (AI) is known to increase adaptation and mitigation capacity, in turn, improving the precision of evidence-based decision making. The proposed study products will inform where greater efforts can be supported for reduced climate change impact. The products will contribute to reliable national commitments to international GHG emissions reporting.

The research products will contribute to realizing African Union development aspirations enshrined in the Agenda 2063, which aspires for a Prosperous Africa based on inclusive Growth and Sustainable Development through "environmentally sustainable and climate resilient economies and communities". The project aligns excellently with the National Development Plan III that recognizes the risks due to climate change as emerging issues that need to be mitigated to increase chances of success of the Plan. The research contributes to realization of SDG 13 by developing technologies that strengthen residence and adaptive capacity. The research products will improve management of the impacts of climate extremes. This will directly and positively impact the Climate Change Department (CCD) to support their accounting on the Paris Agreement.

Study Objectives

1. To develop artificially intelligent algorithms that detect and classify cattle management systems in near real-time within Mubende District from remotely acquired high resolution UAV images and videos.
2. To develop artificially intelligent algorithms that detect and count the number of cattle within each farming system in near real-time in Mubende District from remotely acquired high resolution UAV images and videos.
3. To develop artificially intelligent algorithms that quantify cattle GHG emissions within each farming system in near real-time in Mubende District from remotely acquired high resolution UAV images and videos.
4. To develop an artificially intelligent application for near real-time quantification of cattle GHG emissions from different cattle farming systems in Mubende District.

Study outputs

1. Near real-time algorithms for identifying and indexing cattle farming systems
2. Near real-time cattle detection and counting algorithm
3. Application for near real-time quantification of cattle GHG emissions aggregated from different cattle farming systems
4. Student theses (two for graduate and at least one for undergraduate students)
5. Peer reviewed published papers (at least two peer reviewed papers)

Study impacts

1. Improved and reliable CCD reports supporting formulation of evidence based decision making strategies for climate Change mitigation.
2. AI knowledge applications in other areas through the acquired skill set - Codes that will be developed shall be made open source for other scientists to upgrade, thus harnessing the power of other scientists' ideas and enhancing sustainability.
3. Empowering knowledge and skills shared among stakeholders and farmers.

iii) Background (1 page)

Information relating to Problem: Uganda's livestock sector contributes to the national Gross Domestic Product (GDP) by an average of 4.2% in recent years hence significantly contributing to Uganda's growing economy (UBOS, 2017). The livestock sector is, however, a large contributor to potential global warming through the production of methane (CH_4), Carbon dioxide (CO_2), and nitrous oxide (N_2O) (Rose & Lee, 2009), and has potential consequences for human settlements, ecosystems, agriculture and other socio-economic activities (FAO, 2015). Estimation of GHGs is pivotal in the efforts to reduce GHGs from the livestock sector to continue supporting economic services in a sustainable way (Kipling *et al*., 2016). Thus, to develop accurate GHGs quantification, it is important to establish the quantity of animals that contribute the GHGs. In recent years, advances in Remote Sensing have brought easier and more effective means of estimating GHGs. Satellites have been launched that measure the GHG such as CO_2, NO_2, and CH4 in the atmosphere. However, their data is limited to large-scale estimates. Although Machine learning algorithms can use remotely sensed imagery to perform near real-time cattle counting through video, image analysis and processing techniques such as Convolutional Neural Network (CNN) architectures, this technique has not been sufficiently explored in estimating livestock GHGs. We propose to upscale a methodology, of current study that integrates AI to estimate GHG emissions from cattle, to quantify GHGs from an area in near real-time.

Alignment: Accurate quantification of the GHGs is becoming ever more important given the public interest in the potential outcomes of climate change and the keen interest to invest in developing potential mitigation measures. There is a need for novel research theory, methodologies and practice for effective contributions to meeting the UN SDGs and realizing African Union development aspirations enshrined in the Agenda 2063, which aspires for a Prosperous Africa based on inclusive Growth and Sustainable Development through "environmentally sustainable and climate resilient economies and communities". The project aligns excellently with the National Development Plan III that recognizes the risks due to climate change as emerging issues that need to be mitigated to increase chances of success of the Plan. SDG 13 is the core Climate change-related goal, and our research impact will be measured against contributions to SDG13 Targets (**T**): **T**13.2 and **T**13.b and their respective Indicators (**I**). We propose to launch this innovative approach, to achieve tangible outcomes and transform the fundamental approaches to quantify GHGs inventory in Africa. The overall vision is to transform and standardize the quantification of GHGs inventory approach for Africa, by Africans.

Previous: The study by Kiggundu et al. (2019) to estimate Greenhouse gas emissions from Uganda's cattle corridor farming systems provides a basis for indexing the livestock management systems and expected GHG emission from the study area. In addition, This study will build on the results of the project "Machine learning for estimating sources and sinks: Developing cloud computing-based, artificially intelligent algorithms to quantify livestock and biomass for management of GHG emissions" (MLSS) (Kabenge *et al*., 2022) funded by Global Research Alliance (GRA) and RUFORUM.

Beneficiaries: During the execution of tasks for the MLSS project, Mubende Local Government was involved (District Veterinary Officer for Mubende District, Dr. Ssettaala (+256752838802/786481449). The advantage of taking on the task of near real-time cattle counting is that it ensures sustainability, reinforced capacity building of involved youth to apply AI which will buttress the skills already gained so far in MLSS project. The Climate Change Department (CCD) will be a primary beneficiary of the study product. The head of CCD (Assistant commissioner Bob Natifu, bob.natifu@gmail.com, +256701666778) has been involved during the implementation of MLSS project. The assistant commissioner will be a key pathway to adoption and application of the research product. In addition, the communities affected by the extremes of climate change will benefit from the knowledge acquired during research and resulting data-based decisions for climate change management.

Needs: The development of the GHG Inventory in Uganda is entrusted to the CCD in the Ministry of Water and Environment. However, access to reliable GHG emissions that cover the whole country is delayed due to inadequate technologies deployed and skillsets of personnel leading to ineffective reporting accounting on the Paris Agreement. The communities are eager to receive potential mitigations for the extreme climate changes. The products of the research will feed into better management of the impacts of climate extremes.

Value: The value proposition of this innovation is generating GHG emission from cattle over large areas, in near real-time, reliably and with fewer human resources involved. The intrinsic benefits of AI provide for an approach that yields higher quality results with more application.

iv) Literature Review (1 page max.)

Increasing GHG concentrations affect the earth's climate leading to global warming which in turn has potential consequences for ecosystems, human settlements, agriculture, and other socio-economic activities (FAO, 2015). Livestock production systems contribute an estimation of 18% of global anthropogenic GHG emissions (FAO, 2006; Berhe *et al*., 2020). Cattle contribute 65% of GHG emissions whereas other livestock species have minor emission levels, each of which contributes 7 to 10% of the overall emissions from the sector.

Artificial Intelligence (AI) is increasingly recognized as a very powerful tool in technological advancement. Despite the rising rate of application of AI to address global and societal issues, there is still need for a concerted effort to ascertain how these tools can best be applied in tackling climate change concerns. Deep learning methods have emerged as one of the powerful machine learning techniques and have previously been applied in object detection and counting (Babaiee *et al*., 2021). In order to quantify the GHGs from cattle in near real-time, their number and type of cattle farming systems (CFS) is required as input data to develop a reliable model for GHG estimation.

Advances in video data capture and processing offer new opportunities for using applied remote sensing to count cattle. This provides an opportunity to cover a huge spatial extent in relatively lesser period. Previous studies have applied real-time detection and counting in several applications such as ecological surveys, real-time traffic monitoring in urban areas, highway surveillance, vehicle parking management systems, urban planning, healthcare, and disaster management (Saxena *et al*., 2019). However, this expertise has not been applied in estimation of GHG emissions from cattle yet it has got the potential to provide reliable values.

The technique of object counting which involves the estimation of the number of objects of interest such as cars, people, animals, and buildings in a still image or video coupled with digital image processing, machine learning, and deep learning will be used as applied in the study conducted by Ilyas *et al*. (2019). Convolutional Neural Network (CNN), a type of deep learning model for processing pixel data such as images and videos (Malaainine *et al*., 2021) will come in handy in this study. This is because CNNs have a strong ability to learn and extract spatial information from image and video features and can perform multiple related tasks, such as classification and object detection (Hakim & Fadhil, 2021). This approach is expected to provide reliable results at a relatively lesser time period. The main advantage of CNN algorithms is that they can be applied in real-time scenarios while being computationally less expensive and greater in performance when compared with other approaches (Howard, 2014).

An in-depth understanding of cattle contribution to GHG emissions would be better understood with development of near real-time and reliable approaches that can index Cattle Farming Systems (CFS) and obtain the cattle counts. In Uganda, there are five (5) CFS in the cattle corridor of which grazing accounts for 91.3% of the cattle population which include; tethering, scavenging, grazing, semi-intensive, and stalls (Kiggundu *et al*., 2019). Thus, indexing animal grazing and scavenging area, which account for 88.9% of GHG emissions within the developed algorithm, will facilitate the quantification of GHGs. Similar emissions proportion contributions were reported for cattle in India (Chhabra *et al*., 2009) which alludes to the potential for international application of the research product. The research will develop indexes that quantify the CFS of the area and corresponding factors for quantifying the GHG emissions from estimated cattle counts in near real-time.

The major limitations of reported literature (Xue, Wang, and Skidmore, 2017; Kawamura et al., 2005; Wang, Shao, and Yue, 2019, Shao (2020) is absence of near real-time estimation of GHG emissions. Thus the proposed research is required to optimize the existing techniques that quantifies animals and index CFS. This research will develop a novel approach that in near real-time applies UAV videos, imagery, and artificial intelligence to quantify animals and incorporates developed indices animal systems system to develop a GHGs Inventory for a particular area. Machine learning and artificial intelligence related techniques are well suited to this challenge due to their flexibility and the capability to process large number of inputs and to handle non-linear problems (Ali *et al.*, 2015).

v) Objectives (1/2 page)

The overall objective is to upscale a methodology, of current study that integrates AI to estimate GHG emissions from cattle, to quantify GHGs from an area in near real-time.

The specific objectives include;

1. To develop artificially intelligent algorithms that detect and classify cattle farming systems in near real-time within Mubende District using remotely acquired high resolution UAV images and videos.
2. To develop artificially intelligent algorithms that detect and count the number of cattle within each farming system in near real-time in Mubende District using remotely acquired high resolution UAV images and videos.
3. To develop artificially intelligent algorithms that quantify cattle GHG emissions within each farming system in near real-time in Mubende District using remotely acquired high resolution UAV images and videos.
4. To develop an artificially intelligent application for near real-time quantification of cattle GHG emissions from different cattle farming systems in Mubende District.

vi) Key Research Question(s) and Hypotheses to be tested (1/2)

Research Questions

1. How can artificially intelligent algorithms be developed to detect and classify cattle farming systems in near real-time?
2. How can artificially intelligent algorithms be developed to detect and count the number of cattle within each farming system in near real-time?
3. What is the accuracy of GHG emissions from cattle estimated in near real-time?

vii) Research Approach and Conceptual Framework (2 pages max.)

The study approach will be divided into four work packages (WPs); WP1 is the Near Real-time Counting Algorithm, WP2 is Near Real-time Algorithm for Indexing Cattle Farming Systems, WP3 is the Near Real-time Cattle GHG Emissions Estimation Algorithm and WP4 is the Project Management and Monitoring. This approach ensures that the first three (3) WPs address the objectives while WP4 provides for the interlinkages between the WPs, takes on the coordination, monitoring and administration functions.

The two graduate students supported by two undergraduate students will be at the heart of developing all the research products. This will involve conceptualisation of the algorithm structures, through conducting the ground truthing and data collection activities to integration of the components for the approach. Each graduate student will be tasked to complete two objectives provided during the course of the research. The undergraduate students will be field assistants in charge of collating all the required field data to build the intelligence of the algorithm. One (1) graduate student and at least one (1) undergraduate student will be female.

The CCD and the Mubende District Local Government will be crucial in providing access to farmers during field activities, providing key GHG emission documentation and guidance to ensure functional product from the research. A designated CCD person shall be involved in field data collected. The CCD will also play a crucial role in adoption and dissemination of the research product. A designated person from MAAIF shall be involved in the data collected. The relationships with farmers developed during implementation of MLSS Project will facilitate the collection of field datasets.

Concepts that underpin the approach to carrying out the research

Machine learning related techniques are flexible and have the capability to process large number of inputs and to handle non-linear problems (Ali *et al*., 2015). Undeniably, AI-based algorithms produce increasingly more accurate products and become better with more training data provided to the system. Therefore, the approach will be underpinned by numerous runs, based on accurately collected training datasets, to produce more accurate estimates with every attempt as the machine learning yields better nurtured artificial intelligence. This eventually converges within a predetermined accuracy range supported by the ground truthing datasets. The connectivity between the UAV and ground control station will enable the near real-time data display and logging.

Description of the conceptual framework and innovative nature of this proposed project

For technological advancement, Artificial Intelligence (AI) is imperative especially when it comes to the task that involves GHG estimation from cattle. Despite the growing expertise to apply AI to solve problems in society, they have not been widely applied to tackle climate change. Figure 1 shows the conceptualization of the proposed research study. The deep learning and existing GHG emission data will provide the reference for the accuracy of developed near real-time algorithms given the known accuracy of the product. Such data will come in handy during validation of the developed Near Real-time Counting Algorithm. Cloud computing provides an opportunity to harness the power of parallel computing to process large imagery data from large spatial extents using specially coded commands.

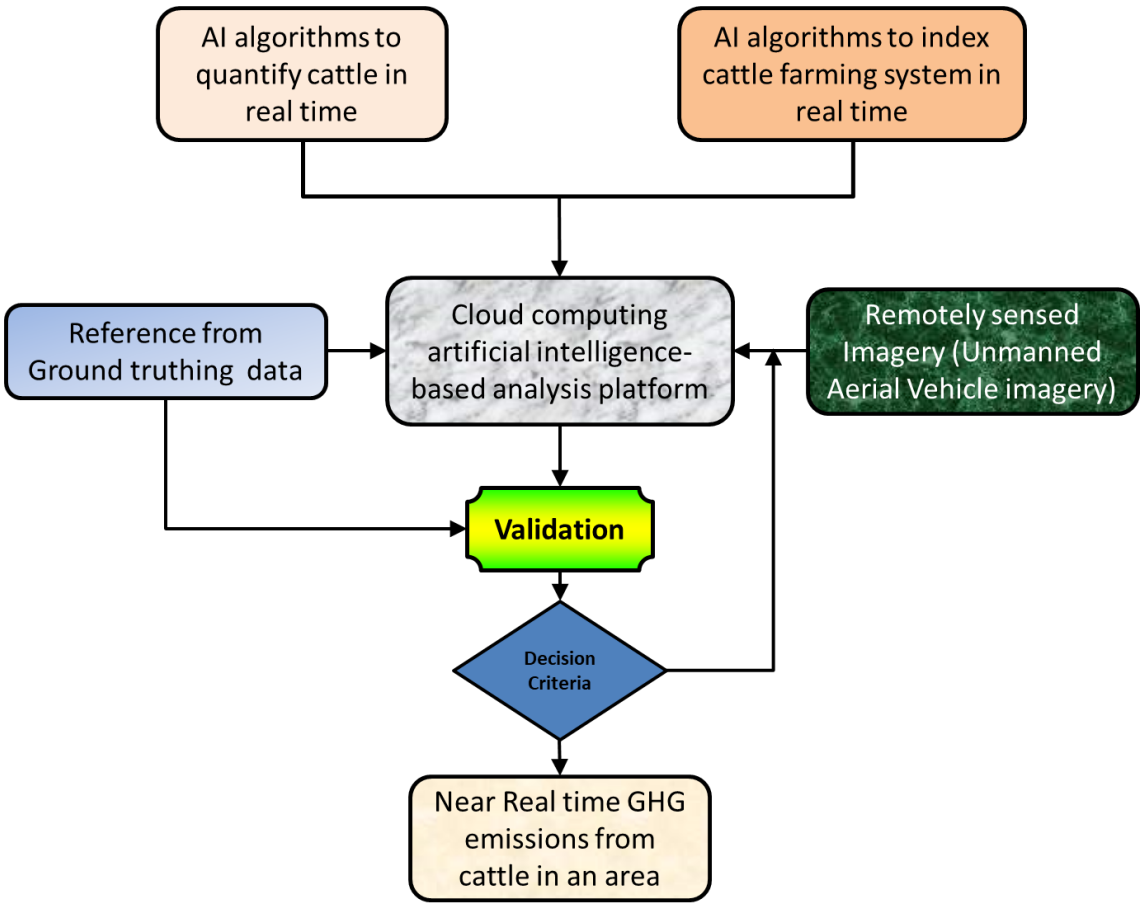


Figure 1: Conceptual framework of the proposed study

viii) Methodology (3 pages max.)

The proposed study will use Mubende District as the study area because it's one of the famous districts in Uganda known for cattle keeping and it's located within Uganda's cattle corridor. The study sites during implementation of the MLSS project for which the methodology is to be upscaled were in Mubende District. Thus, the proposed study will leverage on the relationships and collaborations with stakeholders already established in the district. The study will be implemented through four work packages (WPs). From each WP a series of Milestones have been identified, which will be tracked using Agile Methodology. Agile promotes adaptive planning, collaborative effort of self-organizing and cross-functional teams and their customer/end user, evolutionary development and delivery. The details of the work packages are provided in the following sections:

WP1 is developing an artificially intelligent algorithms that will be trained to identify and classify cattle farming Systems from remotely sensed videos and imagery in near real-time in selected sites within Mubende District. The sub-tasks include i) Identify the cattle farming systems used in Mubende District. This will be done through a survey in the study area and literature review, ii) Collect cattle farming systems information including housing structures, number of cattle per structure, and feed attributes for each cattle farming system in the study area. This will be done through a cross sectional survey in the study area, iii) Acquire videos and imagery for use in developing the algorithm for the study site, iv) Develop and train machine learning algorithms to develop models for cattle farming practices from the acquired videos and imagery in near real-time.

WP1 Milestones (MS1): Report on the cattle farming systems information in the study area, and machine learning algorithms for detecting cattle farming practices from remotely acquired videos and images in near real-time.

WP2 is developing an artificially intelligent algorithm that will be trained to count the number of cattle and their features in near real-time under each cattle farming system in Mubende District from remotely sensed imagery. The sub-tasks will include i) Acquire field imagery for both model training and testing, ii) Develop deep learning (DL) and machine learning (ML) algorithms to count cattle from acquired images. Visual interpretation of which features in the videos and images represent cattle will be conducted and this will be considered as cattle ground truth points on the images. The model will be trained with both the features that represent cattle and those that look like cattle or not. This will train the model better in differentiating cattle from other features. iii) Develop deep learning (DL) and machine learning (ML) algorithms to detect and count cattle from each farming system in near real-time. This will be done depending on the collected information about the characteristics of each cattle farming system under WP1. This information will be used to set thresholds and rules for counting cattle in each farming system. These will include the size of the housing structures, the nature of the farms that is are they divided or not, and the surroundings of the identified cattle.

WP2 Milestones (MS2): Cattle counting algorithm in near real-time, report on the number of cattle in each cattle farming system.

WP3 is developing an algorithm and an application that quantifies GHG emissions from each cattle farming system in near real-time. This will be trained to use the results from each of the counted number of cattle in WP2. The sub-tasks include i) Collect cattle farming systems information including type of animals, weight, weight gain, and feed attributes within the study area. This will be done through a cross sectional survey in the study area, ii) Develop cloud-based computing algorithm that receives products of WP2. iii) Develop a machine learning algorithm to quantifying the GHGs of a particular area in near real-time iii) Development of an application to quantify cattle GHGs emissions in near real-time.

WP3 Milestones (MS3): Cloud based-computing application that quantifies cattle GHG emissions in near real-time.

WP4 is the Project Management and Monitoring that involves interlinkages between the WPs, coordinating, monitoring and administration functions. The objective of WP4 is to ensure the project is successfully managed with deliverables and milestones being achieved to the stipulated timelines of the project activities. The sub-tasks include i) Establish and maintain regular communication with WASCAL-AKADEMIYA 2063-RUFORUM secretariat, ii) Conduct technical and managerial consultation meetings to ensure all team members understand their roles and execute them on time, iii)

Selection of graduate and undergraduate students, iv) Review and approve plans for project activities, v) Facilitate the procurement process of items required for the project to run smoothly and dissemination efforts, vi) Financial, legal, administrative and technical coordination, vii) Oversee ethics and gender issues, viii), Risk management and contingency planning, ix) Develop and approve developed project reports.

WP4 Milestones (MS4): Project progress reports, an artificially intelligent algorithm and application to quantify cattle GHG emissions in near real-time.

Roles of each graduate student and what each graduate student will do including draft objectives/ hypotheses/research questions.

The first graduate student assisted by an undergraduate student will complete the sub-tasks for WP1 and WP2. The research objectives for Graduate Student 1 are:

1. To develop artificial intelligent algorithms for near real-time detection of cattle farming systems in Mubende District using remotely acquired videos and images.
2. To develop artificial intelligent algorithms for near real-time cattle detection and counting within each farming system from remotely acquired videos and images.

The guiding research questions for Graduate student 1 are:

1. How can cattle farming systems be derived from a remotely sensed video and image while leveraging algorithms based on artificial intelligence?
2. What count accuracy of the number of cattle can be derived from an artificially intelligent algorithm based on remotely sensed videos and images in near real-time?

The second graduate student assisted by an undergraduate student will complete the sub-tasks for WP3 and WP4. The research objectives for Graduate Student 2 are:

1. To develop artificially intelligent algorithms for near real-time quantification of cattle GHG from each farming system in Mubende District using remotely acquired videos and images.
2. To develop an application for near real-time quantification of cattle GHG with the use of UAV through integrating the number of cattle identified and counted in each cattle farming systems in Mubende District.

The guiding research questions for Graduate student 2 are:

1. What accuracy of near real-time quantification of cattle GHG emissions from each farming system can be derived from an artificially intelligent algorithm based on remotely sensed videos and images?
2. How can an application for near real-time quantification of cattle GHG emissions with the use of UAV be developed?

Stakeholders engagement during the research especially the national agencies researching, collecting and collating data on climate change - they should not be passive "subjects of research" but active participants.

CCD, which will be the primary beneficiary of the study product will provide guidance about user friendliness and will be a key pathway to adoption and application of the research product. The relationships developed during MLSS Project implementation will be helpful and strengthen during the proposed study. MAAIF will provide relevant information and designate constant persons who will be involved in field data collected. The technical AI experts will assist in the implementation of AI algorithms on the project and oversee the technical products of the project. Mubende District Local government colleagues will be involved in data collection and assist in interpreting results as well as dissemination to farmers. Local leaders will be engaged to understand the benefits of the project and ensure a widely accepted community entry pathway. Farmers play a crucial role in providing access to the study sites and cattle information collected. The stakeholders will be involved during inception, final report back workshop and seminars held by the students to share the product. This will create buy-in and get their feedback on sources of info initially and at the end how this relates to their own knowledge of the situation.

Gender and other cross cutting issues
The implementing team includes a female member. In consideration of gender and any other cross cutting issues, one of the students recruited will be female and gender balancing will always be considered during resource allocations. At all stages, gender considerations will be taken into account through acknowledging the different needs, capacities and contributions of women, men, girls and boys and how to leverage on the results of the study. The impact of technology adoption and gender balance will be assessed.

There is need to elaborate on the expected dataset quality and likely impact.
Quality assurance measures will be put in place to ensure that the developed products are of high quality. These measures will be adhered to at every stage of the project execution in order to eliminate any errors in the processes at an earlier stage.
This research will contribute to contribute to priority research topic 4.1 "Emission of greenhouse gases" of the call when the mentioned major outputs are realized. Additionally, the project will also have the following impact;

1. Improved and reliable CCD reports supporting formulation of evidence based decision making strategies for climate Change mitigation.
2. AI knowledge applications in other areas through the acquired skill set - Codes that will be developed shall be made open source for other scientists to upgrade, thus harnessing the power of other scientists' ideas and enhancing sustainability.
3. Empowering knowledge and skills shared among stakeholders and farmers.

There is also need to demonstrate that the innovation will be conducted in ethical manner.
Ethical considerations will be taken into account at all stages of the innovation. The ethical guidelines provided by Makerere University will be followed as a guideline to conducting morally upright research and achieving reliable results. The impact of the innovation and ethical effects will also be assessed at all stages.

ix) Description of the innovation (1 page max.)
This proposed study will build on the results from the MLSS project. The study approach will aim at developing a Near Real-time detection and Counting Algorithm, Near Real-time Algorithm for Indexing Cattle Farming Systems, Near Real-time Cattle GHG Emissions estimation algorithms. An application will be developed to enable other people quantify cattle near real-time GHG emissions.

Artificial Intelligence (AI) is a very important tool especially in applications that aid in GHG estimation from cattle. Given the level of technological advancement, AI should be widely applied to tackle climate change and has a potential to be scaled up. The proposed innovation focuses on near real-time quantification of cattle GHG emissions since the techniques that involves near real-time detection and counting through video and image analysis has not been explored in estimation of cattle GHG emissions. Precisely, the approach will upscale a methodology of the current study that integrates AI to estimate GHG emissions from cattle, to quantify GHGs from an area in near real-time.

Through CCD, MAAIF, and Mubende District Local Government, information on GHG emissions will be provided to farmers, providing guidance to ensure functional product from the research. The CCD will also play a vital role in adaptation and mitigation of climate change effects through utilizing the research product. The potential impact of the proposed study will be reliable reporting of GHG emissions from cattle for evidence-based decision making.

x) Deliverables and expected results (1/2 page max.)
The project outputs include:

1. Artificially intelligent algorithms to identify and classify cattle farming systems from remotely acquired videos and images in near real-time.
2. Artificially intelligent algorithms to detect and count cattle from remotely acquired videos and images in near real-time.
3. Artificially intelligent algorithms to quantify cattle GHG emissions from each cattle farming system in near real-time.
4. An application for near real-time quantification of cattle GHG emissions with the use of UAV through integrating, the number of cattle counted and identified cattle farming systems.

xi) Gender and inclusion (1/2-page max.)

One of the two graduate students and at least one of the two undergraduate students will be female and gender balancing will always be considered during resource allocations. At all stages, gender considerations will be taken into account through acknowledging the different needs, capacities and contributions of women, men, girls and boys and how to leverage on the results of the study. The impact of technology adoption and gender balance will be assessed. Given that the impact of climate change disproportionally affects women, the product of this research will improve quantifying cattle GHG emissions, feeding into better decision making to mitigate climate changes, This will in the longer term significantly benefit women as well as other vulnerable people. Project implementation will be guided by Makerere University Gender Equality Policy 2009. To ensure timely corrective action arising gender issues will be discussed during every team meeting.

xii) Ensuring Responsible Artificial Intelligence (1/2-page max)

Responsible AI

Due to worrying climatic changes, society is called to provide responsible solutions to the likely adverse impacts of climate change in different sectors. In this regard, Artificial Intelligence (AI) has in the recent years presented potential to transform how real-world problems are being solved including acceleration of climate action via applications such as forecasting, optimization, identification of degradation hotspot. These solutions can be rapidly deployed and scaled across key sectors. However, besides its enormous potential to improve the lives of many, if not responsibly utilized, AI is prone to do more harm than good to the human kind. One of the most fore seen harmful effect of AI Job security among others.

In our Project we shall not take this for granted and thus intend to do the following to ensure responsible use of AI. Building capacity of young generation in AI so they easily adapt to work with the current technological trends. We shall ensure intense efforts in education and training and the development of codes of conduct for all the stakeholders involved so that everyone is aware of their own responsibility where it concerns the development of AI systems with direct impact in society. To reflect societal concerns about the ethics of AI, and ensure that AI systems are developed responsibly, incorporating social and ethical values, we pledge to adhere to principles of accountability, responsibility and transparency as guided by literature.

xiii) Dissemination and communication (1/2-page max.)

To implement and/or disseminate the results of our proposed study, Participatory Extension Approach (PEA) shall be adopted. This is because the approach assumes that individual stakeholders possess much wisdom about their context but their well-being and performance can be improved if they learn more of what is not known to them. The approach also focuses on the expressed needs of various stakeholders and therefore bares a potential of improving the quality of life equally among the stakeholders. As in the MLSS Project, Stakeholder (including farmers, non-governmental organizations, local and central government agencies) engagement during project implementation will be undertaken.

The research products, data collected, reports, lessons learnt from users and stakeholders will be compiled. The outcomes and results from the project will be presented and discussed during the final meeting of the participating stakeholders. The target persons to attend this meeting include; CCD the key beneficiaries of the project, farmers, local government representatives, persons in academia, Ugandan policy makers, technology companies and other persons involved in policy making decisions regarding climate change issues.

It will be important to encourage CCD to upload the research product material on their website to enable the public access the information freely whenever one is interested. Likewise, WASCAL, RUFORUM, and AKADEMIYA2063 are great platforms for disseminating the research products and information. We shall also make use of other means to disseminate information such as social media platforms, email addresses, virtual meetings, and physical meetings where presentations can be held.

Open access publishing will be preferred to communicating and disseminating information to the public especially scientist researchers that would be interested in the results and knowledge from the study.

Furthermore, Exhibitions on both local and online platforms to demonstrate the capabilities of the product will be carried out through sharing video clips in order to promote the product.

xiv) Sustainability (1/2-page max.)

To ensure environmental, social and financial sustainability arising from innovation development and deployment of our project idea, we are firstly proud to mention that we have proposed a "green" project where most of all our activities if not all does not lead to any GHG emissions and thus environmentally sustainable. We shall ensure that there is zero waste generation during the project design process and execution and team members will be advised to always recycle the generated wastes to minimize GHG emissions

Secondly, as a matter of social sustainability, our dissemination approach ensures all stakeholders are brought on board thus taking into consideration every interest and this will significantly influence the acceptability of the results and thus the ease of scalability. In this regard, the proposed project conception integrated sustainability by engaging CCD of the Ministry of Water which will be the primary beneficiary. Therefore, the acquired knowledge and skillsets will be easily sustained.

Finally, in response to the concern of financial sustainability, we intend to work closely with the responsible arms of the government along with the non-governmental organizations. Furthermore, our pool of technical capacity that we shall attain at the end have the ability to generate income since this knowledge can easily be transferred to other disciplines like improving processes in manufacturing industries among others.

xv) Project Management

a) Team organization and qualification (1/2-page max.)

The overall lead of the project will be the PI, Assoc. Prof. Eng. Isa Kabenge with Assoc. Prof. Anthony Gidudu as a technical support colleague. They will work closely for the duration of the project. The team will work with trained young technical AI experts (Evet Naturinda, Fortunate Kemigyisha and Emmanuel Omia) to oversee the development and implementation of AI algorithms on the project. The project will also engage two graduate students, at least one of whom will be female and two undergraduate students at least one of whom will be female. Figure 2 shows the Team structure.

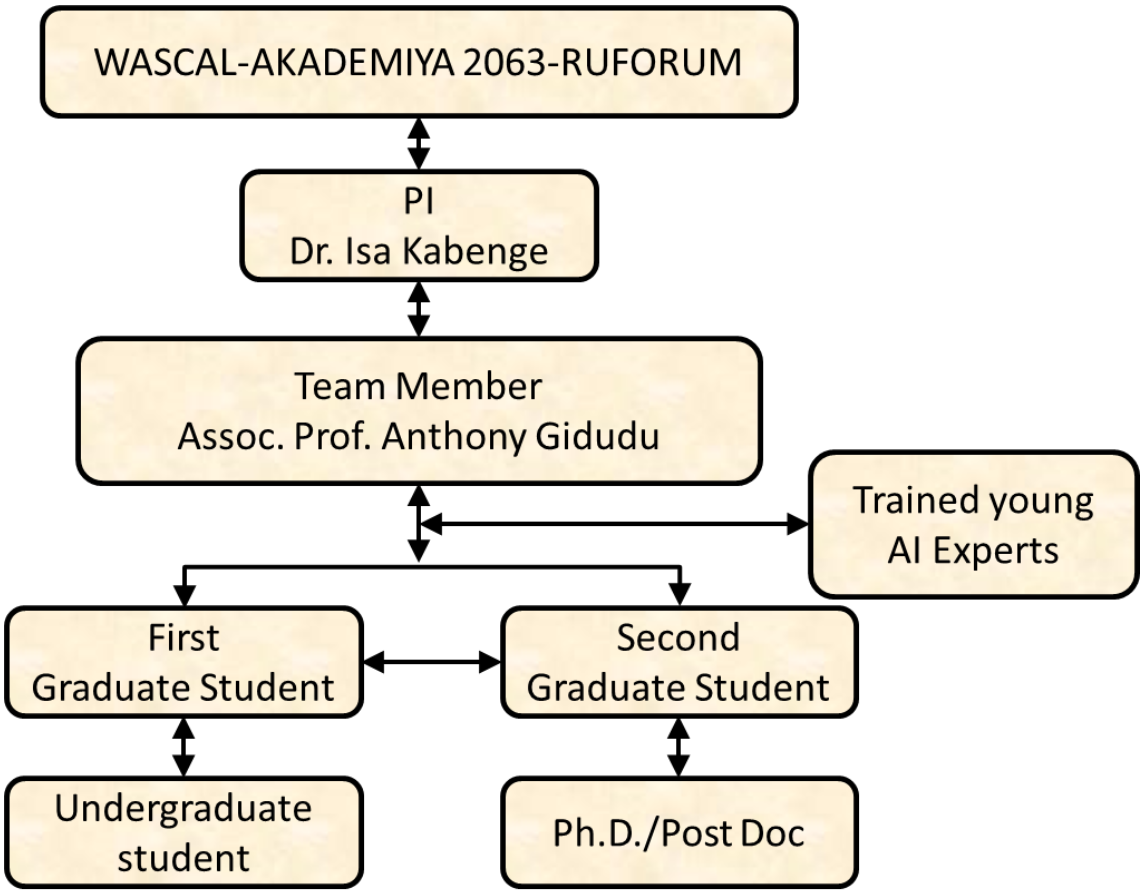


Figure 2: Project Team organisation

The role of each team member must be clearly described.
The project lead will be Assoc. Prof. Eng. Isa Kabenge who will be in charge of overall project implementation and responsible for the project's administration. Dr. Kabenge will be in charge of communication with WASCAL-AKADEMIYA 2063-RUFORUM. The Assoc. Prof. Gidudu will work closely with the Project PI to plan for project implementation and supervision of the project. The Dr. Kabenge and Dr. Gidudu will review and select graduate and undergraduate student applications, technical guidance of the students and will be the co-supervisors to the graduate students' research. The CCD and MAAIF will provide relevant information and designate constant persons who will be involved in field data collected. The young technical AI experts will assist in the implementation of AI algorithms on the project and oversee the technical products of the project. The remote sensing firms will supply imagery and data collection equipment (spectral camera and UAVs).

b) Monitoring and evaluation (1 page max.)

The work package (WP) approach adopted provides for inbuilt monitoring and evaluation of the research. Each WP has clear activities, timelines, milestones and products attached to it. Thus, the project progress will be easily monitored during implementation and any delay quickly spotted and

underlying issues corrected. The reporting to RUFORUM and Makerere University financial accounting will be helpful the developed Logical Framework will be used during monitoring and evaluation of the project progress.

Indicate clear milestones that will demonstrate progress whilst describing how the project will monitor progress towards milestones

The identified milestones (MS) for each work package (WP) include;

1) WP1 Milestones (MS1): Report on the number of cattle in the study area, cattle counting algorithm.
2) WP2 Milestones (MS2): Report on the cattle farming systems information in the study area, algorithm for indices for animal management practices and animal performance.
3) WP3 Milestones (MS3): Cloud based-computing platform, algorithm for Near Real-time Counting of cattle
4) WP4 Milestones (MS4): Project progress reports, a ML-based artificially intelligent algorithm to quantify GHGs from cattle.

The milestones that have been identified will be tracked using Agile Methodology. Agile promotes adaptive planning, collaborative effort of self-organizing and cross-functional teams and their customer/end user, evolutionary development and delivery. Agile project management is adaptive, emphasizes collaboration, flexibility, continual improvement, and high-quality results. Thus, progress and emerging challenges within and between work packages will be discussed by the team. Working ideas in a particular work package will be adopted and adapted to challenges in other work packages.
Project impact will be measured by the rate of adoption and application of the research product. Feedback from CCD and other users will feed into evaluating and quantifying interest and impact. Impact evaluation strategies will include “pre-post comparisons, product quality, cost of application and schedule (Unterkalmsteiner et al., 2011).

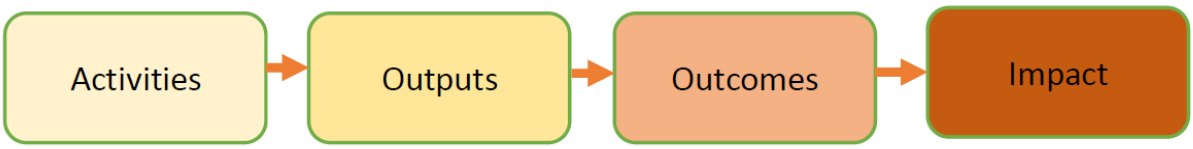
Including the effectiveness of the partnerships and sustainability of the solutions

Associate Prof. Eng. Isa Kabenge will lead and has teamed up with Associate Professor Anthony Gidudu, from the Department of Geomatics and Land Management, CEDAT, who together form an excellent team for the proposed project. Between them interdisciplinary expertise is harnessed from agricultural and biological systems engineering as well as geomatics and land management to effectively deliver the proposed research. The two have exceptionally worked together to implement the MLSS Project successfully. The primary beneficiary Climate Change Department (CCD) shall provide a key pathway to adoption and application of the research product.

The ML and deep learning (DL) codes that will be developed shall be made open source for other scientists to upgrade, that way harnessing the power other scientists’ ideas and enhancing sustainability. The two M.Sc. students and two undergraduate students will benefit from the knowledge acquired during research. These students will provide skilled manpower and ensure sustainability of the developed product.

c) Results Framework (1 pages max.)

Please prepare concise narrative of the results framework with a diagrammatic illustration using the format below



RESULTS FRAMEWORK

Figure 3 illustrates a concise narrative results framework.

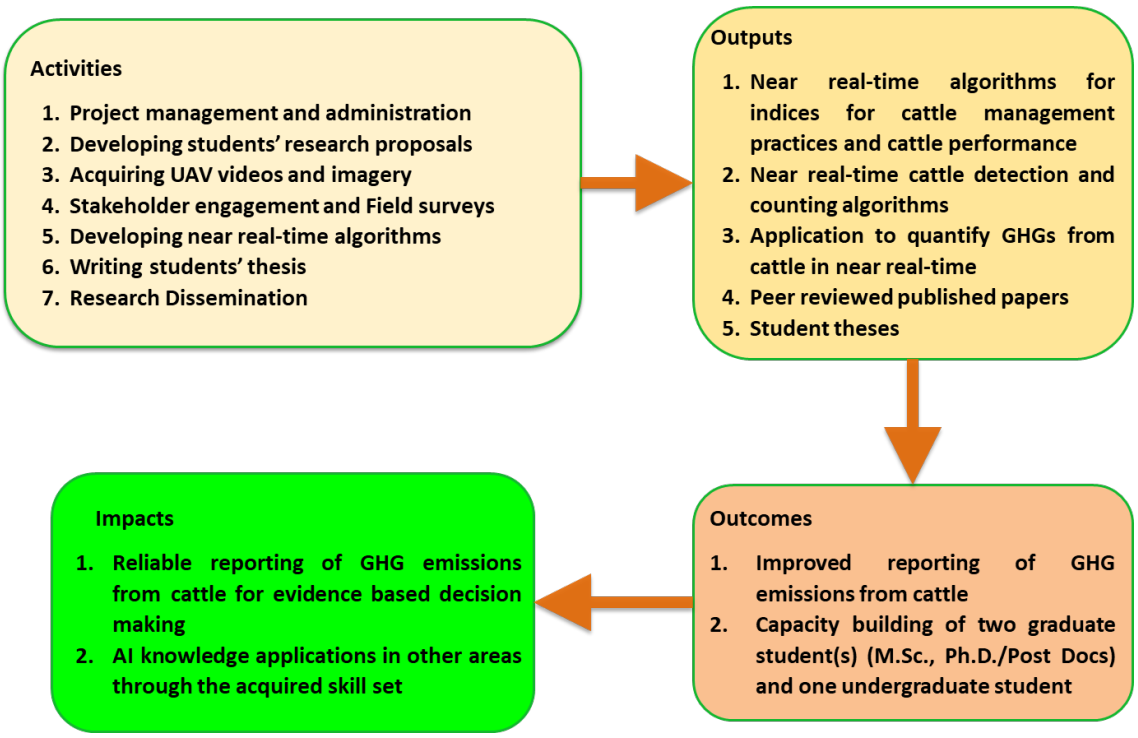


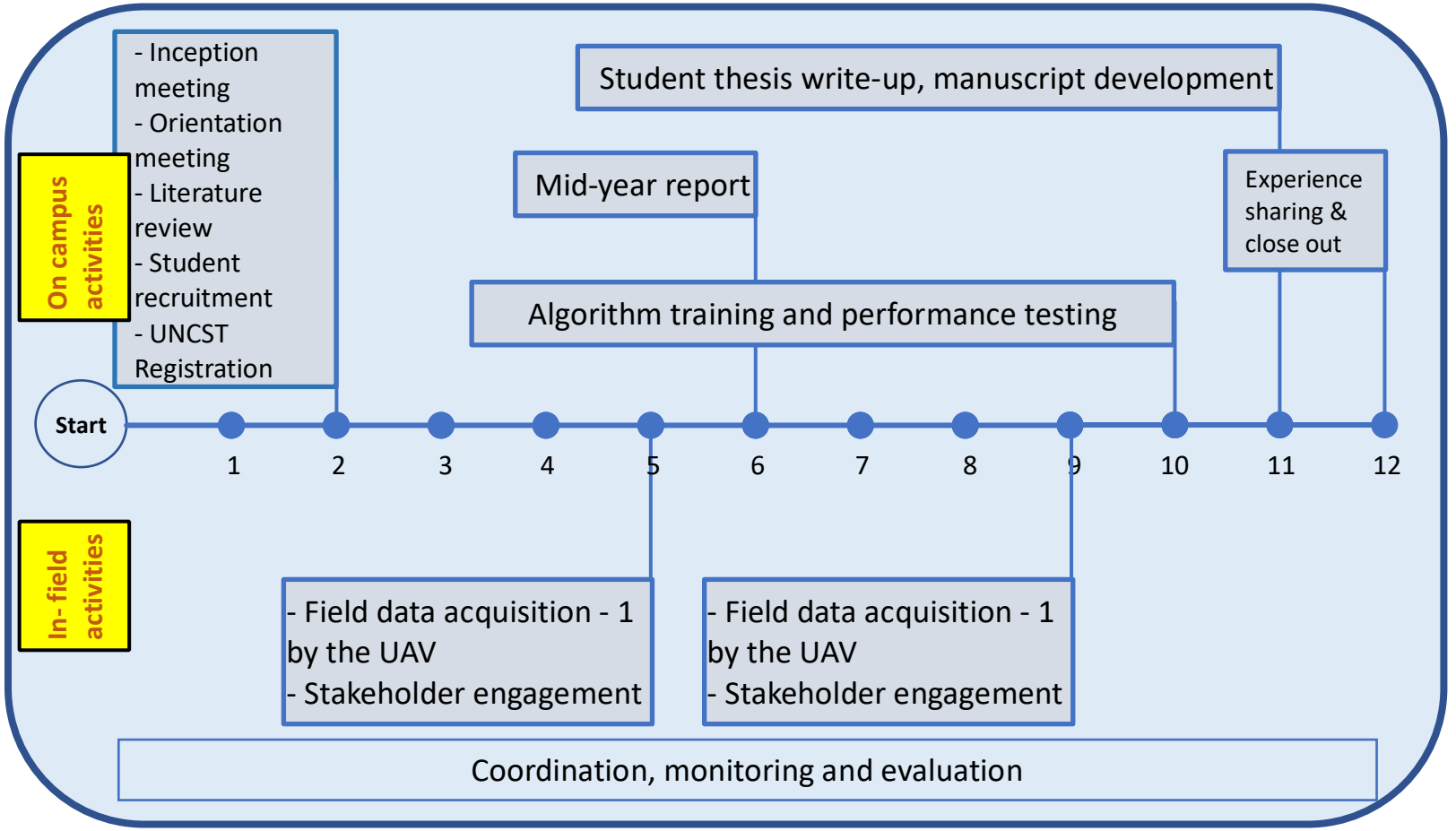
Figure 3: Project concise results framework

xvi) Budget (1page max.)

Give the anticipated cost of your project, with explanatory notes where necessary using the attached budget template. All budgets must be in United States Dollars (use the template plate provided).

xvii) Timeline

All innovation research projects are 12 months.



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