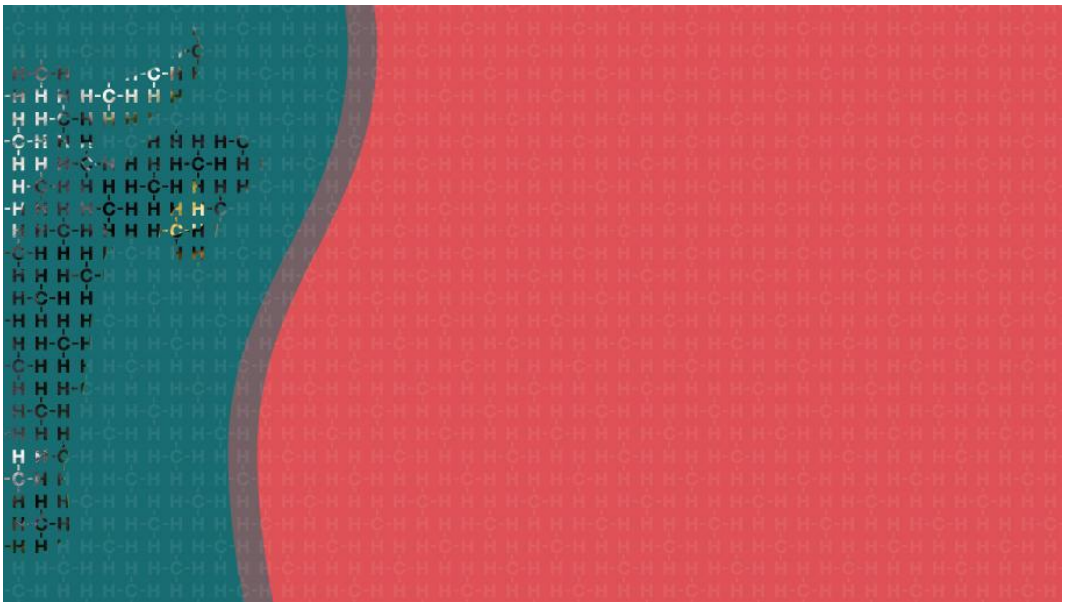
PUBLICATION

Investment Roadmap: Digital Services for Livestock Methane in LMICs



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Solutions Groups

Digital Services for Livestock Methane Management Solutions Group

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Summary

In many low-and-middle income countries (LMICs), livestock productivity remains low, despite the growing demand for animal protein. At the same time, greenhouse gas (GHG) emissions intensity is relatively high, and absolute emissions are starting to rise. Livestock productivity can be significantly increased through the implementation of established good practices, and the appropriate use of technologies and resources. Implementation of these measures can increase productivity and reduce emissions against business-as-usual conditions. However, in contrast to higher-performing livestock production systems, many LMICs largely lack the advisory, extension, and related services that enable producer knowledge and uptake of such measures. The result is stagnant growth in livestock productivity and high emission intensities.

At the same time, governments and the livestock sector are under pressure to reduce GHG emissions, but they lack data and related insights to formulate and monitor effective policies and to be able to report progress on climate commitments. The limited availability of data, tools and capacities to streamline mitigation and adaptation measures into national climate policies also hinders the ability of governments to attract climate finance. These constraints also prevent international financial institutions (IFIs) from making tailored investments that produce quantifiable GHG emissions reductions and allow progress tracking in relation to national policy implementation.

Digital services for livestock (DSL) can help address these interrelated challenges but are currently underutilised. By enhancing access to and dissemination of advisory services to increase the uptake of good practices, DSL can support increased production efficiency and can leverage the climate- and financial co- benefits of mitigation interventions. DSL can provide data for GHG emissions accounting which can strengthen policy frameworks and lead to increased opportunities to access climate finance.

This roadmap was developed to provide guidance to i) governments to integrate DSL into livestock development and climate strategies and to strengthen national inventories and reporting; and ii) IFIs to mainstream DSL into their investment portfolio, to be able to support governments to reach their climate and development goals and to develop reliable Measurement, Reporting and Verification (MRV) systems for monitoring climate co-benefits of their investments.

The Solutions Group Approach

This roadmap was developed by a Solutions Group convened by Livestock Data for Decisions (LD4D) and the Climate and Clean Air Coalition (CCAC). The Solutions Group brings together a diverse team of experts working in livestock, climate, finance, policy, and digital innovation, to co-develop practical, evidence- based guidance to increase investment in the adoption and scaling of DSL.

The Solutions Group model is designed to:

– Collaborate with decision makers to identify the critical challenges they face and provide evidence-based insights and practical actions to address those challenges;
– Seek solutions to challenges by fostering collaboration and dialogues across disciplines and investment actors (e.g., public, private, research, and multilaterals); and
– Bridge the gap between evidence, policy and practice by ensuring that outputs are driven by and focused on the needs of decision makers such as governments, IFIs, donors, and other implementing partners.

The group's activities included:

– Understanding enablers and challenges related to DSL adoption at the value chain level, within policy and investment frameworks and in GHG accounting and MRV systems;
– Developing a shared Theory of Change and Problem Statement to define outcomes and pathways to impact;
– Identifying evidence and practical case studies to help countries streamline the adoption and scale-up of DSL; and
– Co-developing guidelines to promote effective policies and strategic investment.

By bringing these diverse perspectives together, the Solutions Group ensures that this roadmap is not only technically robust, but also practical, policy-relevant, and aligned with global climate and development goals. It creates a foundation for deeper collaboration and concerted action across organisations and sectors to promote DSL that delivers methane and GHG emissions reductions and development co-benefits for all value-chain actors, across the entire livestock sector.

Introduction

The Methane Challenge in Livestock Systems

Methane is a short-lived climate pollutant that lasts in the atmosphere for about 12 years and accounts for about 30 percent of the rise in global temperatures since the Industrial Revolution (IEA, 2024). Because of the short-lived nature of methane in the atmosphere, lowering future methane emissions will lead to a near-term reduction in global temperatures (Rogelj and Schleussner, 2019). Recognising the potential of methane emissions reductions in achieving the Paris Agreement, 159 countries have signed the Global Methane Pledge to reduce methane emissions by 30 percent by 2030. Livestock emit around 31 percent of anthropogenic methane emissions (enteric fermentation contributes 26 percent and manure management contributes 5 percent), and fast action on methane emissions in the sector is critical towards achieving the ambition of the Global Methane Pledge (UNEP/CCAC, 2022).

However, in many LMICs, methane from the livestock sector is not only a climate concern but also a development issue. Improving productivity in the sector directly impacts food security and nutrition, rural livelihoods, and economic development, and can help meet the rising demand for animal protein in LMICs. Farming systems within LMICs vary significantly, encompassing both high- and low-emissions-intensity production systems across and within individual countries. For example, emissions intensities in smallholder cattle farming systems in western Kenya range from 20 to more than 1000 kg CO 2 e/kg crude protein (averaged for milk and meat), and some of the high-input systems emit considerably lower emissions intensities, reflecting potential to adapt similar practices and lower the existing levels of emissions intensities (N’dungu et al., 2022).

By focusing on sustainably enhancing productivity, rather than increasing animal numbers, to meet increasing demand for livestock products in LMICs with rapidly growing populations and incomes, countries can change their methane emissions trajectory and bend the emission curve downward (Salmon et al, 2025). Achieving productivity increases through already available strategies, both at the animal level and by optimising efficiency across the value chain, offers an opportunity to reduce the projected absolute GHG emissions from the livestock sector by 20 percent or more (FAO, 2023).

Entry points exist to lower methane and GHG emissions intensity and, in some cases, absolute emissions, through technical advisory services that provide information on improved quality and availability of locally grown feed, feed additives, improved grazing management, improved herd structure, improved animal health, welfare, and breeding practices, and alternative ways to manage manure. However, significant gaps in livestock service delivery exist in LMICs, often due to the relatively smaller scale, informal nature, and often remote location of livestock producers and highly mobile nature of pastoralists, which makes service delivery costly.

The Role of Digital Services for Livestock

DSL can offer a cost-effective solution[1] to reaching livestock producers and sector actors at scale with good practices that enhance productivity and reduce methane emissions intensity. Currently, however, the adoption and scale-up of digital tools in many LMICs remains limited due to inadequate digital public infrastructure, low policy integration, and weak investment models.

Further, many LMICs underreport or omit emissions intensity reduction efforts from their national climate targets, due to inadequate or absent MRV systems. They cannot collect data on livestock diets, forage resources and availability, herd dynamics, genetic improvements, animal health, and GHG accounting methods. These factors pose a challenge for livestock sector actors, including IFIs and policy makers, to account for development and climate objectives in the sector and to intervene with corresponding measures to mainstream climate co-benefits into national climate commitments to increase access to climate finance. DSL offer an opportunity to enhance the capacity of IFIs and governments to leverage the co-benefits of methane measures. This can be achieved through DSL providing access to and dissemination of tailored advisory services, data, tools, and market and weather information services to sector actors (CCAC, 2024; Özkan and Kohler, 2024).

Definition of Digital Services for Livestock (DSL)

In this roadmap, DSL refer to technologies and platforms coupled with human resources to enhance the socio-economic and climate co-benefits of GHG mitigation efforts. DSL supported by advisory services facilitate the adoption of interventions through provision of location and context-specific information, traceability, and market access. DSL offer innovative ways to reach producers at scale with the knowledge and tools necessary to improve productivity, strengthen resilience, and enable reduction of emissions intensity and direct methane abatement. DSL also generate valuable data that supports GHG MRV

which can facilitate access to climate finance and increase investment, and that can provide governments and IFIs a platform to track and mainstream methane mitigation into their policies and investment portfolio.

Types of DSL include i) Productivity enhancing tools; ii) GHG accounting tools; iii) Weather information services; iv) Animal tracking tools; and v) Market access platforms (Figure 1- Solid lines refer to the direct impact of the DSL while dotted lines are considered to be indirect). A more detailed overview of the types of DSL and their features in relation to methane abatement in the livestock sector can be found in the CCAC Technology and Economic Assessment Panel Report: Role of Digital (Extension) Services for Livestock on Tackling Methane Emissions (Özkan and Kohler, 2024).

– *Productivity-Enhancing and emission reduction Tools:* These tools aim to improve feeding, animal health and reproductive function, and grazing management, as well as

to support emission reduction through inclusion of methanogenic supplements and improved manure management, and are designed to improve farm efficiency and productivity. They contribute towards emissions intensity reduction through productivity gains. While these tools are not always climate-focused, the data they collect on feed composition, milk or meat yields, animal health and reproductive status, and herd composition can be essential for calculating emission intensity, and strengthening GHG estimations and MRV systems.

– *Animal Tracking Tools:* These tools are designed to monitor animals' location, health, and behaviour. The information gleaned from these tools can improve farm management by providing data for better decision-making, enable early detection of potential health issues, strengthen fertility and reproductive performance, monitor grazing behaviour, and enhance security against theft or loss.

– *Weather Information Services:* These tools increase producers' knowledge and ability to anticipate weather events, which leads to improved farm management practices (e.g. bringing animals to higher ground in the case of flooding, increasing feed crop production, improving feed storage and planning, improving pastoralists' access grazing sources, mitigating heat stress through alert systems).

– *Greenhouse Gas Accounting Tools:* These tools are designed to measure, estimate, and track GHG emissions from livestock systems. Data generated by productivity-enhancing and advisory tools can feed into these systems to support the calculation of emissions intensity and absolute emissions. These tools are critical for strengthening MRV systems, supporting national inventories and NDC reporting.

– *Market Access Platforms:* These platforms connect producers, producer groups, agrodealers, and buyers, and offer transparent information on input and output market prices, provenance of animals, and the production system they originate from, creating a reliable and trustworthy environment for trade. Producers' increased access to inputs enables improved productivity, while increased access to market information and buyers improves producers' ability to plan and sell animals and animal source products at peak age or quality and at the best price.

Foundational Recommendations

Credit: World Bank

Several foundational recommendations are provided below which support a process to strengthen the integration and use of DSL across the livestock sector. These recommendations propose a multi-stakeholder driven process which would initially identify or establish a suitable stakeholder group to drive the process; undertake or oversee an analysis of the operational context and enabling environment at a country, region or other administrative level; explore opportunities and pathway specific recommendations with the intention of producing an action plan to operationalise interventions that strengthen DSL; and serve as an advisory group to support investment design.

These recommendations also seek to strengthen DSL synergies and coherence across the four pathways laid out in this Roadmap. It is anticipated that the stakeholder group would be linked with National Digital development and Climate Change initiatives.

Recommendations:

- **Establish a multi-stakeholder DSL working/advisory group:**
  - This group should work closely with any other groups tasked with digital development, which may be operating at an economy-wide scale.
  - Provide support for the design and implementation of assessments (described below).
  - Provide advice to Investment design teams, investment managers and national government departments on how to optimise the inclusion of DSL into investment designs and national programmes.
  - Provide linkages to national digital policies and programmes and oversight of livestock specific initiatives.

- **Undertake a Country-level Assessment of Digital Services for Livestock** : through desk-study and in-country stakeholder consultation, build on existing analysis and understanding, and assess the status of DSL integration, the policy framework, potential gaps, and opportunities to strengthen the contributions of DSL (the specific assessments have also been identified in the pathway sections).
  - **Mapping of the existing digital ecosystem:** Identify stakeholders, map the current offer of DSL in the country, assess the potential for scaling, as well as the needs for interoperability, and costs to development. Note: In many countries this work has already been done (e.g., by the World Bank) so it is important not to duplicate efforts.
  - **Mapping of available DSL and gap analysis:** Determine how existing digital tools can provide data on productivity and help to quantify GHG emissions as well as their potential to transfer knowledge to help producers to improve farming practices. Promote knowledge exchange between app developers, governments and producer organisations. Analyse existing gaps where DSL could play a role but are not yet in use.
  - **Map Existing Data Ecosystems:** Identify current data flows (and potential data silos), sources (public and private), and critical data gaps.

- **Establish a sub-group which focuses on fostering Public–Private Partnerships** (e.g., between relevant government departments/ministries and livestock, DSL, and information communication technology industry actors).
  - Create forums or platforms for stakeholder collaboration.
  - Set standards for data confidentiality and protection.

  - Identify common, pre-competitive challenges and facilitate stakeholder engagement and partnerships to find solutions and improve data flows.
  - Private sector livestock digital service providers might partner in the delivery of government extension services or be linked or referred through government services.

- **Develop a Digital Services for Livestock Action Plan**
  - Working through the stakeholder working group, build on the proposed assessments and analysis to determine priority actions and incorporate these into an action plan document.
  - Align the action plan with other digital development and environment initiatives.

- **Track and periodically report on progress with the incorporation of DSL into low emission livestock sector development.**

Investment Pathways

The roadmap is structured around four mutually reinforcing pathways which are critical to the adoption and scale of digital tools for livestock systems:

1. Building digital public infrastructure to lay the foundation for the growth and sustainability of DSL
2. Integrating DSL into national livestock and climate policies to support an enabling environment, increase climate finance, and achieve national climate goals
3. Mobilising livestock data ecosystems to enhance the quality, accessibility, and use of data for MRV
4. Leveraging private sector investment for last mile delivery to ensure scaling and adoption by livestock sector actors

Depending on the priorities of specific governments and IFIs and the level of DSL development in a given country, these four pathways can be focused on individually or at the same time. The four pathways are interlinked in several ways, with each one supporting and strengthening the others through shared data, coordinated investments, and joint capacity building efforts. This creates a unified approach where progress in any single pathway helps advance the overall goals across all areas. The pathways are presented in the next section.

Pathways

Building digital public infrastructure for digital services for the livestock sector

Key messages

– The goal of Digital Public Infrastructure (DPI) is to provide a foundational platform that ensures public accessibility and transparency of public services and data sets (e.g., farmer/livestock registries, feed databases, breeding indices).
– Creating and supporting DPI with public funding can establish the necessary digital infrastructure building blocks and reduce the cost for the private sector to develop and deploy DSL.
– Important DPI building blocks can be sector-agnostic (e.g., payment systems) or livestock-specific (e.g., livestock registries, feed databases).
– Capacity development and stakeholder dialogue improves the ability for private sector DSL developers and farmers to use and connect to DPI.

Overview

Digital Public Infrastructure (DPI) is the foundation for the other pathways, reinforcing the development and sustainability of the other three pathways. The Center for Digital Public Infrastructure defines DPI as “an approach to addressing socio-economic problems at population scale. This approach combines open technology standards with robust governance frameworks to encourage private community innovation to address societal scale challenges such as financial inclusion, affordable healthcare, quality education, climate change, access to justice and beyond.” According to the Center, there are broadly five categories of DPI which are (i) Identifiers & Registries (ii) Data Sharing and Models (iii) Signatures and Consent (iv) Discovery and Fulfilment (v) Payments. DPI can be non-sector specific (such as a payment platform) or be livestock sector specific, such as a livestock farm registry. Without foundational DPI, developers must build DSL as full stack solutions meaning that the tool developer builds and operates all the building blocks necessary for DSL. Very often, this means that every DSL provider is investing and re-

creating building blocks alongside multiple other service providers. The idea of DPI is to identify such foundational digital building blocks as pre-competitive enablers and hence drive private sector capital to focus and develop value adding and demand driven DSL.

Outside the livestock sector, one of the most successful examples of DPI is India's Unified Payments interface. This Interface has fostered innovation and competition by creating a centralised, public payment processing system that any financial institution can connect to. This helps close gaps in financial inclusion and facilitates financial transfers to vulnerable people. Another example of DPI is of AgDataHubs[2] which were developed as part of the World Bank funded AICCRA programme in Kenya, Zambia, Mali and Senegal. The AgDataHubs ingest and integrate public, private and citizen sourced data needed for developing agro-meteorological advisories and makes these datasets available to producers, agri-businesses and other boundary organizations through a dashboard as well as application programming interfaces. In the livestock sector, DPI can include producer and animal registries, feed libraries, pasture monitoring through remote sensing and citizen science, pond monitoring and breeding indices. While national animal registries (see Uruguay case study below), farmer registries, feed libraries, monitoring, and breeding indices might be most appropriate for some countries, these approaches can also take a zonal or compartmental approach where they only incorporate livestock and producers in specific geographies or within specific production systems. DPI also includes the physical digital infrastructure needed for basic connectivity to digital technologies, such as satellite systems (in the case of remote sensing) and mobile networks for rural internet access.

Inclusive and transformational DSL requires funding and participation of both the public and private sector. Many agricultural research institutes invest in public goods for the livestock sector without digitising those resources, such as breeding indices and feed libraries. There have also been philanthropic efforts to strengthen these resources, such as Global Methane Hub's support of the Global Farm Animals Ration Programs. These public resources have great potential to be integrated into agritech DSL that repackage the information into user-friendly interfaces for producers. When designing investments into these resources, governments should consider the best practices to make that data accessible and interoperable between different digital platforms. The public sector should fund the building and operationalisation of foundational DPI which crowds in private sector investments to develop and deliver DSL for smallholder producers and other livestock sector actors. As this model to delivering DSL scales, the public sector should also lay the foundation for creating a data ecosystem to power new markets, such as carbon markets, within the various smallholder livestock production systems.

Goal

The goal is to ensure that the necessary DPI is in place, providing support to digital development and livestock services in particular, so that effective DSLs are available, accessible and affordable to livestock producers and sector actors. The provision of DSL delivers public goods and efficiently creates an enabling environment that is beneficial to all stakeholders engaging in digital development.

Approach

If DSL development and deployment is driven entirely by private capital, there is a very real risk that efforts will be duplicated, resources will be used inefficiently, parallel and incompatible systems will be set up, and that private capital funded companies and developers will only address a small group of producers who can afford such services. This unintentionally leads to exclusion of smallholder producers who might not be able to afford these services. However, creating and supporting foundational DPI with public funding can substantially reduce the cost for the private sector to develop and deploy DSL. By fostering a competitive market of private DSL providers, costs also come down for farmers and livestock producers to access these advisory services. This will ultimately lead to more affordable DSL and thereby start addressing underserved market segments that may not be included in the absence of DPI. This also encourages the development and deployment of long tail of DSL, which address multiple small market segments.

The success of foundational DPI will be visible when both public and private sector-based digital innovations and services use DPI to build and deliver DSL. More importantly, these services are affordable not just for large-scale producers but also for traditionally underserved and often overlooked target groups. Success of DPI also mobilises and stimulates a community of innovators to refine and create newer services and offerings around the DPI. Though technological in nature, DPI benefits when combined with enabling infrastructure. For instance, DPI can best deliver its intended outcome when there are policy enablers and good governance as well as sufficient human and institutional capacity. A key enabler is also a forum where public and private actors can exchange knowledge and feedback on various topics.

It is important to identify existing datasets and layers, such as geographic information systems, land-use and soil maps, and ensure that those data sets are publicly accessible and interoperable, through suitable open application programming interfaces. Datasets in the form of registries can be particularly useful. These registries can be built on farm

enterprise registration, vaccination or subsidy records, or the use of Radio Frequency Identification tags, and other animal identification schemes in livestock that provide animal traceability (see case study from Uruguay below).

Governments and IFIs should also explore how data generated and held by public research institutions, national development programmes, and development assistance projects (such as breeding indices and feed libraries) can be anonymised, digitised, and made publicly available and interoperable with other datasets. Agritech companies could liberate these datasets, repackaging information in user-friendly formats for producers, if they are accessible. Governments should consider the appropriate data sharing platforms and approaches.

Successful DPI will mobilise and stimulate a community of innovators to refine and create newer services and offerings. DPI interacts with effective policy, good data systems governance, and sufficient human and institutional capacities. DPIs, though technological in nature, benefit when combined with enabling infrastructure. For instance, DPIs can deliver their intended outcomes when there are policy enablers and good governance, as well as sufficient human and institutional capacities needed to drive DPI powered DSL. A key enabler is also a forum where public and private actors can exchange knowledge and feedback on various topics.

Recommendations

To kickstart a virtuous cycle of DPI and community-led innovation, governments and IFIs should consider investing in the following:

- **Mapping and analysis of existing DPI:** map the current DPI blocks in the country, including non-livestock sector specific DPI as well as livestock sector specific. For example, systems which support digital identities, digital payments, DPI supporting government social insurance and emergency programmes, mobile cell phone coverage.
- **Review existing national digital investment plans and strategies** to understand future DPI upgrading (this will likely require cross-Ministry outreach). Consider the opportunities existing DPI presents, and where there are gaps. Assess the potential for scaling, as well as the needs for and costs for further development.
- **Consult with DSL creators and developers:** identify challenges and priorities to strengthen DPI from a user perspective.
- **Identify livestock specific DPI building blocks,** including farmer, livestock, feed, and breeding registries.

- **Identify existing registries and other national, regional, compartmental or commodity datasets** of livestock producers, their livestock and production performance (that can provide multiple benefits as DPI for agritech start-ups).
- **Identify and make easily available other public datasets, which serve as useful data layers:** Clarify if these data layers are publicly accessible and interoperable, through suitable open application programming interfaces.
  - Explore producer farm-level data sharing options and protocols to meet data protection and privacy standards to benefit farmers by streamlining digital tool adoption by reducing the amount of data producers need to upload into each app, while also ensuring the data remains under producer ownership to easily transfer from one application to another.
  - Make accessible data generated and held by public research institutions, national development programmes, and development assistance projects (such as breeding indices and feed libraries)
  - Develop database inventories, identifying all data sets that are available, and support appropriate data sharing platforms and approaches.
- **Capacity building - Raise awareness with stakeholders of the value of DPI and engage in planning how to strengthen DPI and the necessary human and institutional capacities:**
  - Technical support to producers on uploading farm-level data into DPI streamlines adoption and acceptance of new DPI.
  - Workshops and manuals can also train DSL creators on how to integrate data from DPI into DSL.
  - Conduct dialogues and consultations to address challenges and areas of interest and concern, such as data privacy
  - Facilitate inter-Ministerial and multi-stakeholder dialogue, to ensure effective coordination and data integration.
  - Developing policies to build and support DPI will require capacity building for policymakers to understand the interactions between livestock productivity, national statistics gathering, and GHG emissions.

Case study: Uruguay Cattle Registry

A rancher herds cattle in Cruz de los Caminos, Uruguay. Uruguay's National System of Livestock Information electronically tags animals, allowing the government to effectively track animal health, and ensure traceability. The system also provides critical data to improve farm-level output and enable Uruguay's livestock sector to manage productivity gains and reduce emissions intensity.
Photo: Eduardo Amorim.

Uruguay created a National System of Livestock Information in 2006 and remains one of the few countries with such a system in place. The registry merges data from the Sistema de Identificación y Registro Animal with data from the Sistema Electrónico de Información de la Industria Cárnica. Each animal is tagged with a Radio Frequency Identification chip, which can be read by scanners that automatically transfer data to the electronic database managed by the Ministry of Livestock, Agriculture and Fisheries. This system began as a response to an outbreak of foot-and-mouth disease. It allows for rapid response to any disease outbreak - the government knows where each animal is, who owns it, and which other animals it is with.

While emerging from an animal health context, this system has become a public infrastructure to support the sector's innovation. This system allows Uruguay's meat industry to meet even the most stringent quality controls for export markets, whether for environmental concerns or health regulations. Traceability does not stop at the farmgate but continues as the cattle pass through meat processors all the way to the final consumer. Uruguay's meat commands a premium on international markets compared to South American peers, reaching over 100 markets.

The system also provides critical data to improve farm-level output by merging data from other sources. It incorporates GIS data on each rural parcel from the General Directorate of the National Cadastre and on roads and administrative divisions from the Ministry of Transportation. This allows veterinarians to map out neighbouring farms and potential disease outbreaks to improve health outcomes for cattle. It also allows breeders to map

activity data from cattle and pinpoint which cattle to breed and when. In dairy systems the chips are being used also for individual identification of animals for both milking equipment and accessories and automated calf feeders.

The data the cattle registry provides enables Uruguay’s livestock sector to better manage the beef and dairy subsectors, leading to productivity gains and reductions in emissions intensity. This is a clear example of DPI enabling sector growth and innovation.

Integrating digital services for the livestock sector into national policies

Key messages

– The goal of this pathway is to guide governments and IFIs on how DSL can be integrated into national policies and investments.

– Mapping the existing policy environment and digital ecosystem provides an overview for synergies and facilitates prioritisation.

– DSL can play a role in filling data gaps and facilitate knowledge exchange among developers, governments, and farmer organisations.

– Integrating DSL into national policies and investments supports the development of robust MRV systems, including farm-level data collection and GHG emissions calculations. This enhanced monitoring capability generates evidence-based results for GHG emissions mitigation efforts such as progress towards Nationally Determined Contributions targets, which strengthens countries' ability to attract climate finance.

Overview

With the rapid growth of DSL, many national governments, both in high-income and LMICs, have not adequately integrated DSL into their national climate policies. In some countries, there is limited knowledge and awareness of DSL’s potential to improve productivity, promote food security, support livelihoods and address climate change. Many governments also have limited technical and institutional capacity to develop policy frameworks that effectively integrate DSL and lack alignment in policies that reflect livestock development and climate change. This may lead to missed opportunities to attract climate investments. In countries where robust DSL exist, national policies often overlook them, limiting their scale and role in reducing GHG emissions and to inform and support public policy. This policy gap curtails the potential for public-private sector

interactions and represents a missed opportunity to strengthen the enabling environment for private sector growth in this area. Similarly, most IFI investments have not optimally integrated DSL into investment projects.

MRV approaches are a critical component of policy systems. Despite the critical role in supporting policy development, verifying results relating to policy commitments, such as Nationally Determined Contributions (NDC) reporting, and facilitating access to climate finance and tracking climate commitments, many LMICs lack robust and reliable MRV systems. Key challenges include limited data collection, especially animal activity data, data fragmentation, data frequency, and lack of locally developed emissions factors which leads to low reliability of emissions data. When data is available, it is not easily aggregated or integrated with other data sets. Strengthening MRV systems is covered in detail in Pathway 3.

Goal

The national policy framework embeds and supports digital services for livestock, to achieve policy objectives and promote the use of digital approaches.

Governments: Mainstreaming DSL into national policies can accelerate the reduction of GHG emissions intensities in the livestock sector by generating evidence-based results and deploying specific tools tailored to each country's context. Interoperable DSL can deepen the provision of extension and in-person advisory services, to complement existing public and private extension services, and further close gaps in capacity and increase productivity, thereby reducing GHG emissions.

Integrating DSL into national policies can help countries collect better farm level and value chain data, which in turn supports improved calculations of GHG emissions from the livestock sector. These improved calculations support policy development and refinement, internal and external reporting (including on climate commitments), and domestic resource mobilisation. They also raise the confidence of climate investors to make financing available. A clear framework to support DSL provides opportunities to create coordinated and coherent MRV systems with data systems and relevant GHG accounting tools in place, attract climate finance investments in the livestock sector, and support achievement of NDC targets.

IFIs: If countries streamline DSL into their national policies, this will create an enabling environment for the uptake and use of DSL, enhancing their impact on productivity and emission reduction. IFIs will be better positioned to quantify the GHG emission impacts of

their investments by leveraging data from national livestock MRV systems to measure project outcomes. Knowing that they can quantify the GHG emission impact of investments, IFIs will have more confidence to invest in countries for emission reduction projects in the livestock sector. Similarly, the private sector will have more confidence to invest, collaborate, and to share data.

Approach

Integrating DSL into national policies to scale delivery and adoption of DSL, improve GHG reporting systems (inventories), and support improved MRV systems can help identify opportunities for GHG emissions mitigation. DSL not only strengthen MRV systems by providing accurate and timely data, but also generate diverse, more reliable datasets that support better decision-making. A robust MRV framework built on DSL can foster national ownership by broadening access to data and incorporating insights from a wide range of stakeholders.

DSL can be integrated into policy in the following ways:

– Identify types of DSL and their potential to improve existing or new policy development;
– Enhance technical capacities to use DSL with GHG accounting features to make more informed emissions reduction targets and to produce quantified results of potential mitigation measures;
– Enhance institutional capacities and communication between Ministries and NDC updating institutions to ensure alignment between policy frameworks e.g. National GHG Inventory informing NDCs; and
– Strengthen data flows and interoperability.

Recommendations

The following steps can be customised by national governments and/or IFIs interested in supporting DSL integration into national policies and investments. The undertaking may not be a linear step-by-step process that follows the same procedure in each country, but the activities outlined here can be adjusted to fit the context of a particular country or IFI programme.

– **Policy mapping and coherence assessment:** Assess current integration of digital aspects in existing policy frameworks across sectors (livestock, climate, information communication technology development) and determine alignment with the NDCs and

finance goals. (The policy mapping should be used in conjunction with mapping of the existing digital ecosystem and a mapping of the available DSL and gap analysis – see Foundational Recommendations).

- **Build capacity for policymakers:** Develop targeted training programmes and awareness-raising initiatives for stakeholders across agriculture and livestock, environment, finance, technology sectors, as well as IFIs to strengthen the understanding of the links between DSL, MRV systems, productivity and climate finance and the value of mainstreaming DSL into policy frameworks.
- **Strengthen inclusion of DSL into public livestock sector services:** Build both technical and institutional capacity, particularly within government bodies and extension services, to effectively deploy and operationalise DSL
- **Develop a prioritised list of policy actions.** These actions may be incorporated into a broader DSL National Action Plan (or regional or commodity-specific action plan(s)) proposed as part of the Foundational DSL Recommendations. The aim of the action plan would be to mainstream DSL into livestock sector and related climate development policies and programmes.

Case Study: Dairy Interventions for Mitigation and Adaptation (DaIMA) streamlining DSL into investments

A farmer tends to his dairy cattle in Uganda. The DaIMA programme works with dairy farmers across Uganda, Kenya, Rwanda, and Tanzania to implement climate-smart practices that reduce greenhouse gas emissions while increasing milk production through improved animal health and production efficiency. The initiative is supported by a USD 200 million investment from the International Fund for Agricultural Development (IFAD) and USD 150 million in financing from the Green Climate Fund.
Photo: A. Mottet (IFAD).

The DaIMA programme is working in Kenya, Rwanda, Tanzania and Uganda to reduce greenhouse gas emissions from the dairy industry while increasing milk production through measures that improve production efficiency.

The International Fund for Agricultural Development (IFAD) has invested USD $200 million and leveraged climate finance through another USD $150 million from Green Climate Fund (GCF), a total of USD $350 million, reaching 2.5 million rural people (15 million people indirectly being impacted) in Kenya, Rwanda, Tanzania and Uganda. The DaIMA programme aims to reduce the GHG emissions from the dairy industry by over 2 million t CO2 e over a 20-year time period and increase milk production by over 30% through improved veterinary services, enhanced extension and breeding services, and better access to climate information. It aims to increase capacities, enhance MRV systems and policies, and mobilise local financial sector for directing climate finance to private sector. DaIMA provides direct facilitation in the implementation of NDCs in each of the participating countries (IFAD, 2025). The assembled finance model including grants and senior loans is an added value for countries to bridge the gap in accessing climate finance

for the vulnerable and underrepresented communities.

The programme uses and leverages the use of three DSL: GLEAM-i; feed balance sheet; and feed formulation tools.

GLEAM-i

GLEAM-i was used to calculate the expected impact of the programme on GHG emissions, GHG emissions intensity and food security. It was also used as a tool to train relevant stakeholders to inform the national MRV system and inventories by using collected activity data and generating Tier 2 emission factors. The programme will inform national MRV systems and calculate GHG emissions biannually.

National feed balance sheets

A national feed balance sheet is being developed and used to take into account the seasonal fluctuations in feed availability and requirement. A full description of developing a feed balance sheet can be found in Mottet and Assouma (2024).

Feed formulation tools

These tools are being used to balance rations for requirement, seasonal variations in feed availability and quality, and the locally available feed, with the aim of reducing GHG emissions intensity.

Mobilising livestock data ecosystems to enhance Measurement, Reporting, and Verification

Key messages

– The goal of this pathway is to offer guidance to governments and IFIs for how to advance DSL to complement data collection and management capacity.
– Integration and utilisation of existing data streams can strengthen the evidence base for informed policy decisions and optimises available resources.
– Streamlined access to quality and harmonised data supports countries to estimate and report their GHG emissions and the impact of mitigation measures. This supports countries to attract climate finance and report towards their NDCs and for IFIs to track the impact of their investments.

– Core data requirements need to be defined and matched with the capabilities of the existing data ecosystems.
– Establishing legal frameworks and creating policy levers can leverage data standardisation, governance, and sharing.

Overview

Despite growing recognition of the importance of livestock sector emissions in national climate strategies, many LMICs face significant challenges in collecting the high-quality data required to meet Tier 2 reporting standards under the Intergovernmental Panel on Climate Change (IPCC) framework. Most governments currently lack the capacity, infrastructure, and resourcing to systematically gather the data necessary for robust Measurement, Reporting and Verification (MRV) systems[3]. This gap in data quality and reporting capability has implications. Without the ability to demonstrate mitigation progress at higher tiers of reporting, countries risk missing out on critical opportunities—such as accessing climate finance, participating in carbon markets, and formulating evidence-based policies (e.g. NDCs) tailored to their national contexts.

Although valuable data exists within the broader livestock data ecosystem, much of it is fragmented and siloed. Often, it is collected and retained by private sector actors—including commercial farms, veterinary service providers, offtakers and aggregators and agritech firms—and is not readily available in public databases. Furthermore, data is gathered for differing purposes, using diverse methodologies, indicators, and formats, creating interoperability challenges and undermining national efforts to integrate and scale MRV systems. This fragmentation is compounded by a lack of clear data governance frameworks, limited incentives for data sharing, and concerns around data privacy and protection.

Without intentional design processes that include inputs from relevant stakeholders, and the experiences and data they possess, the evolution of these systems risks missing key insights into on-the-ground practices, progress, and challenges, and reinforcing existing inequalities. To address these challenges, coordinated investment in livestock data ecosystems is essential—not only to improve reporting capacity, but to unlock climate finance, enhance policy effectiveness, and support a just and inclusive low-emissions transition for the sector.

DSL across LMICs have the potential to generate substantial data volumes to improve understanding of livestock productivity and emissions estimations. The absence or inaccessibility of this data represents a potential critical missed opportunity to support

climate action, as livestock data being generated could serve multiple essential functions: establishing productivity baselines, tracking emissions over time, enabling targeted mitigation interventions, and supporting robust MRV systems.

Goal

This investment pathway envisions a robust, inclusive, and interoperable livestock data ecosystem that serves the needs of governments, IFIs, the private sector, and other key stakeholders. By investing in the systems, partnerships, and incentives necessary to mobilise relevant data across public and private domains, the pathway strengthens national capacity for MRV while unlocking broader benefits across the sector.

For governments, the outcome is clear: with streamlined access to high-quality, harmonised data—from both public and private sources—countries will be better positioned to accurately estimate and report methane and other livestock-related GHG emissions. This empowers them to transition from Tier 1 to Tier 2 reporting, access to climate- and development finance, and support evidence-based policy frameworks. Governments will also be better equipped to track their progress against NDCs and livestock mitigation commitments. In addition to strengthened data systems supporting MRV, greater investment in DSL will support improved productivity measurement, broader service delivery offerings, and wider reach to producers and other value chain participants.

For **IFIs**, improving data flow, and interoperability to support multiple uses and re-use avoids duplication, and represents an efficiency and enhanced value for money. Establishing governance structures that strengthen the data ecosystem and enable innovation, and the evolution of data systems contributes to the sustainability of outcomes. Improved national data systems contribute to IFI investment-level results reporting.

Strengthened data systems can contribute to additional resource mobilisation, including internal domestic resources, as well as external resources. The availability of transparent and verifiable data across countries and livestock production systems, enables stronger alignment with global climate finance initiatives. It enhances IFIs’ ability to track how investments contribute to national climate goals, demonstrate value for investment, and offer new, lower-cost options in their portfolio of climate finance tools. Improved data sets also enhance the opportunity for peer-peer, and cross-country learning and knowledge exchange, grounded in evidence.

A coordinated livestock data ecosystem can also present new business opportunities for the private sector, technology providers, and innovation actors. The demand for interoperable tools, analytics platforms, and scalable DSL can drive investment, foster innovation, and support commercial models that serve both public good and private gain. Ultimately, this pathway enables a future in which all players—from livestock producers and tech innovators to policymakers and donors—are connected through a shared, data-driven infrastructure that advances both environmental goals and economic development.

Approach

DSL across LMICs have the potential to generate substantial data to improve understanding of livestock productivity and emissions estimations. The absence or inaccessibility of this data represents a potential critical missed opportunity to support climate action, as livestock data being generated could serve multiple essential functions: establishing productivity baselines, tracking emissions over time, enabling targeted mitigation interventions, and supporting robust MRV systems.

A pathway to enhanced methane emissions reduction lies in strategically breaking down barriers that prevent or limit data collection, data sharing, and capacity to use data, including through the promotion and application the FAIR principles: data is Findable, Accessible, Interoperable, and Reusable (Wilkinson et al., 2016). Improved sharing of existing data potentially has a high return on investment. However, this will require a solid understanding of barriers and solutions that align incentives correctly. Approaches which can help support this include facilitation of industry-wide dialogue to identify shared sector data priorities; highlight mutual benefits of data sharing for all ecosystem actors; identification of bespoke solutions to better align incentives for prioritised data sets.

This section seeks to advise governments and IFIs on how to advance DSL to complement data collection and management capacity, including bringing privately generated digital data into public MRV systems. By promoting the integration and use of existing data streams, countries can cost-effectively advance from Tier 1 to Tier 2 reporting—particularly valuable in resource-constrained contexts. This approach not only enhances reporting on climate commitments but also strengthens the evidence base for informed policy making, optimising available resources by building upon established digital infrastructure rather than creating parallel systems. Success requires targeted interventions to facilitate outcome-orientated data systems and data sharing while ensuring that the growing digital livestock sector contributes meaningfully to national climate objectives.

To realise this pathway, a country would require a coordinated and multi-stakeholder strategy. For some recommendations, the Ministry responsible for the livestock sector would need to coordinate across different Ministries including Ministries of Environment and Climate, Planning, Finance, and the National Statistics Office, on shared responsibilities such as harmonised administrative layers and developing interoperability standards.

Recommendations

Recommended components of an approach to mobilise data and strengthen MRV include:

- **Define Core Data Requirements:**Clarify the minimum essential datasets needed for MRV.
- **Map Existing Data sets and the ecosystem that generates them:** Identify current data flows (and potential data silos), sources (public and private).
  - Identify from where core data requirements are met, and where critical data gaps exist.
  - Undertake an inventory of data sets and the levels of access.
  - Consider approaches to addressing data gaps – through improving access to existing data or identifying methods to capture new data.
- **Streamline Data Analysis Process**
  - Develop a clear process of data collection, analysis, storage, and security.
- **Improve Findability and Accessibility of Data:**
  - Develop a centralised or disbursed livestock data library, or other means to inventory datasets collected and stored by disparate sources, to make them more easily accessible and usable by members of the data ecosystem.
  - Strengthen tagging of data sets and inclusion of metadata.
  - Develop voluntary codes of practice that encourage data sharing.
- **Improve Interoperability of Data:**
  - Develop integration mechanisms for existing datasets, enabling them to be used for different applications with a clear indication of the data format that is required.
  - Establish forward-looking, standardised protocols for data collection and metadata documentation.

  - Ensure data anonymisation and compliance with privacy regulations. This will require addressing data ownership and privacy issues.

- **Leverage Policy and Regulatory Tools:**
  - Create policy levers to support data standardisation, data sharing and governance.
  - Establish legal frameworks that define roles, responsibilities, and data privacy safeguards.
- **Cross-link with Parallel digital development Initiatives:** Coordinate with broader digital and governance action plans, including those from pathway 1.
- **Enhance Capacities:**Invest in training for data management, modelling, and emissions reporting across public and private institutions.
- **Foster Public–Private Partnerships:**
  - Create forums or platforms for stakeholder collaboration.
  - Develop pre-competitive partnerships to improve data flows.
  - Facilitate and incentivise private sector data sharing.
- **Clarify Climate Finance Entry Points:**
  - Define the data requirements for accessing carbon markets and results-based financing.
- **Highlight the Cost of Inaction:** Conduct an assessment of the opportunity costs of weak MRV systems (e.g., forgone climate finance, inability to report on climate commitments, inability to make a strong investment case based on quality data).

Case study: Netherlands' Public–Private Data Ecosystem for Livestock GHG Reporting

Cattle graze in Kinderdijk, the Netherlands. The government of the Netherlands supports a partnership between universities, dairy companies, feed firms and tech providers to generate farm level and individual animal emissions data. Photo credit: Songyang (Unsplash).

The government of the Netherlands supports a partnership between universities, dairy companies, feed firms and tech providers to generate farm level and individual animal emissions data.

The National Inventory Entity (NIE), housed within RVO (Netherlands Enterprise Agency) and supported by National Institute for Public Health and the Environment (RIVM)'s Pollutant Release and Transfer Register (PRTR) framework, oversees reporting to UNFCCC and the EU under IPCC compliant methodologies.

Foster Public–Private Partnerships & Clarify Climate Finance Entry Points

Wageningen University & Research (WUR) leads research partnerships with industry to generate farm level and individual animal emissions data. This includes The Global Methane Genetics initiative, which measures methane per cow via automated sensors (e.g. in milking robots) linked to DNA profiles. The initiative also supports the Low Carbon Dairy project where WUR partners with FrieslandCampina, Unilever, Nestlé, Agrifirm, ForProducers, Lely, Rabobank, Duynie, to pilot emissions-reducing feed, microbiome manipulation, robotics, and life cycle assessments. The breeding firm CRV collaborates with WUR to translate methane measurements into breeding values for bulls and cows, embedding low methane traits in livestock. The dairy processor FrieslandCampina pays premium prices to producers whose milk comes from low emission herds, integrating methane metrics into sourcing contracts. Agri tech companies, such as Lely, supply

milking robots and sensors capturing feed intake and gas output on certain farms, feeding anonymised data into life cycle assessment databases. Feed companies (Agrifirm, ForProducers, Duynie) provide data on feed composition, ration adjustments and resulting emission reductions.

Leverage Policy and Regulatory Tools

RVO (as NIE) coordinates the national inventory system: defines institutional responsibilities, quality assurance and quality control (QA/QC) programmes, and methodology protocols under IPCC and EU/UNFCCC guidance. Statistics Netherlands (CBS) and RIVM integrate administrative data from animal registers (data on animal diets and productivity), and the calculations of methane emissions are executed by research departments at WUR. The Government supports public-private R&D through substantial funding – including a EUR 40 million investment in Dairy Campus and ongoing innovation project support – while facilitating data-sharing agreements among research partners.

Improve Findability and Accessibility of Data & Improve Interoperability of Data

Through shared datasets, the Dutch livestock sector can attribute GHG emissions to individual farms, enabling targeted mitigation via breeding, feed, and manure management. The inventory reflects progressively lower emissions: for example, genetic selection (through increased productivity and accompanied changes in feed intake and feed efficiency) and feed optimisation contribute to continuous methane reduction trends, while nutrient excretion per cow declines. Institutional trust anchored in transparent QA/QC regimes and joint governance - underpins willingness of private actors to share sensitive data knowing it enriches national reporting.

Leveraging Private Sector Investment for Last Mile Delivery

Key messages

– The goal of this pathway is to provide guidance to governments and IFIs on how to leverage private sector investment to support scaling DSL at the last mile.
– DSL providers can benefit from support at all phases of their business cycle. This includes: incubation; business planning, bringing to market, and scale-up; service and new feature development; and reaching the last-mile.
– Reaching small-scale and subsistence producers can be achieved by co-financing pilots for new customer segments, aligning market incentives for private sector actors, and by

identifying public-private partnerships or government intervention to reach customers who cannot be sustainably reached by the private sector.

– Scaling DSL across the livestock sector supports evidence-based decision making, increasing the generation and use of farm-level data. This builds a foundation for improved MRV systems that integrate data from a variety of actors and production systems.

Overview

While there has been a proliferation of innovation in DSL across LMICs, DSL has yet to reach scale in many LMICs, particularly among small-scale and subsistence producers where the potential for productivity gains and reductions in methane emissions intensity is largest. Common challenges to reaching underserved customer segments include the perceived low profitability by the private sector of serving non-commercial producers and micro, small, and medium enterprises (MSMEs); low literacy and/or digital literacy of these customer segments; low smartphone and/or feature phone penetration of these customer segments; geographically disbursed producers with limited aggregating structures such as producer groups, cooperatives; limited telecom infrastructure in rural and remote areas; and limited access to finance and business development services for new and existing DSL service providers looking to scale and expand their service offerings.

To reach a critical mass of livestock producers and sector actors and thus make significant gains in livestock sector productivity and reductions in methane emissions intensity, the private sector needs support derisking their investments. This would allow them to expand existing DSL offerings, create new offerings tailored to different customer segments (e.g., low literacy / digital literacy users), and develop tailored business models to reach stratified customer segments (e.g., bundled services, subscription models). Public-private sector investment will vary across countries depending on how developed their DSL ecosystem is, who is benefiting from it, and the overarching socioeconomic development and environmental goals.

Goal

The goal is for the public sector and IFIs to catalyse digital innovation, derisk and support investments from the private sector to scale DSL services. This would enable the mainstreaming of practices that enhance productivity and reduce methane emissions across actors in the livestock sector, particularly underserved segments of the market.

Approach

To stimulate innovation and support market readiness of DSL, public and IFI investment should build on existing programmes and initiatives that are already in place to strengthen digital development, innovation, and MSME development, ensuring the livestock sector can increase its access to these initiatives. Building on public investments in DPI (see Pathway 1), and supporting policy frameworks (Pathway 2), IFIs and national governments can invest in measures that stimulate innovation, lower barriers and reduce risks. Close collaboration with private sector stakeholders will combine skill sets from both sectors and strengthen the approach. A range of options are presented in the following recommendations section; each will need to be evaluated and adjusted to meet context-specific needs.

Furthermore, access to finance is a critical enabler supporting last-mile delivery of DSL. It is important to identify the financing needs of the DSL innovation sub-system and develop models and approaches with local financing institutions to address these needs. IFIs and governments can consider how they can increase the availability and accessibility of finance, and how its supply can be de-risked, through instruments such as first loan loss guarantees and blended finance

Governments and IFIs can also help to shape and stimulate innovation, creating an enabling environment in which DSLs can flourish. In countries where the DSL landscape is nascent or where there are significant gaps in service offerings, investment can support incubation, acceleration, and market research of DSL offerings. This is an opportunity for collaboration with universities, Ministries of Trade, Finance, information communication technology, and/or private incubation organisations involved in this type of work.

The provision of business development services is complimentary to catalysing innovation, incubation, and acceleration of DLS. Governments and IFIs can facilitate access to business development firms to support business planning and development, fund willingness-to-pay studies to guide the development of subscription, pay-per-use or other pricing models. MSMEs also require support with approaches to marketing and piloting services in new geographies and with under-served segments of the livestock sector. The public sector can also consider facilitating access to legal advisory services; support to navigate small business administrative issues, address product registration and to provide advice on emerging issues such as data sharing, data protection and privacy. These services could potentially be co-located in a business development hub.

The private sector has been grappling with the challenges of last-mile delivery in many contexts. Public institutions can engage in dialogue and lesson learning with the private sector and consider partnering with them. The private sector frequently utilises aggregation models, such as cooperatives, producer organisations, and community groups to jointly access services, inputs, and markets. These aggregation models can also help scale the adoption of DSL.

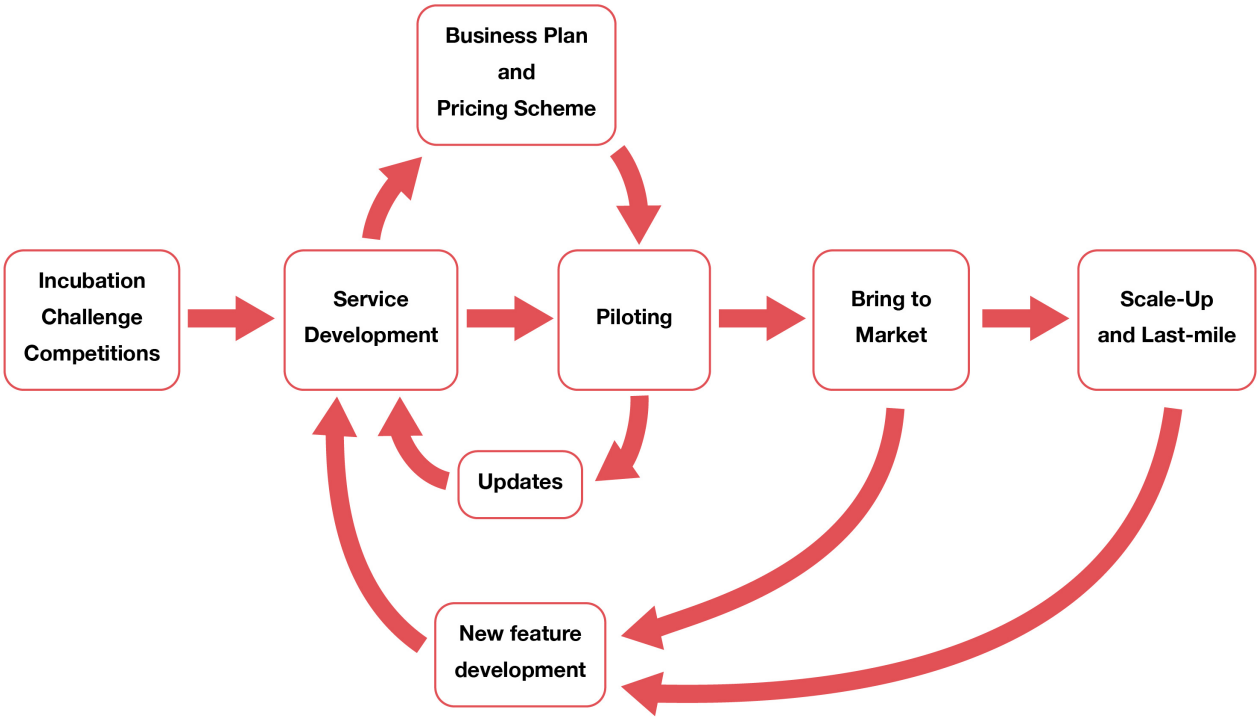
To support accessing under-served markets, it may be possible to leverage existing public digital solutions, systems and infrastructure, bundling private sector digital services into public safety-net, agricultural advisory and other services. This might take the form of public-private partnerships where the incentives for MSMEs are limited and risks are high. It may also require regulatory approaches or publicly financing specific technologies or platforms.

Recommendations

To understand the current DSL landscape, a stakeholder informed consultation is proposed, that considers the state of digital literacy and field uptake of DSL, the state of the innovation system, and investment climate. This assessment will provide an evidence-based entry point to guide strategy development. Elements that the assessment could consider include:

– Identifying existing programmes and initiatives that support digital development and innovation, the progress they are making, resources available and lessons learned;
– Identifying current financing approaches, barriers, and future opportunities; and
– Conducting a lesson learned, information exchange, or benchmarking exercise of leading countries to identify best practices to support innovation and scaling of digital services (including successes from outside the livestock sector).

After completing an analysis of the existing DSL landscape, the public sector and IFIs can use a DSL lifecycle approach (Figure 2) to determine where to invest to catalyse further development of DSL. IFIs and governments should seek to crowd in philanthropic and private investment into innovation funds and other partnership approaches.



- **Support a range of measures that strengthen innovation and support incubation of DSL.**
  - Fund market research for digital tools with a focus on hard-to-reach markets and/or the bottom of the pyramid customers.
  - Partner with or create a public sandbox facility for DSL developers to test and refine digital innovations.
  - Establish business incubator and accelerator programmes – provide MSMEs with mentoring and business development services.
  - Finance and support MSME incubator and related events, challenges and prize competitions, or hackathons to foster creativity and generate new product- or service ideas.

- **Business Planning, Bringing to Market, and Scale-up**
  - Facilitate the engagement of business development firms with digital MSMEs to support business planning and development.
  - Finance willingness-to-pay studies to develop subscription models or pay-per-use models.
  - Finance development of marketing materials.
  - Finance pilots in new geographies and with under-served segments of the livestock sector.

  - Provide legal advisory services; support to navigate small business administrative issues, address product registration and to provide advice on emerging issues such as data sharing, data protection and privacy

- **Service and New Feature Development:** In countries where DSL exist but there are gaps in service offerings, investment can be used to accelerate the service development of existing or new DSL offerors. This can include:
  - Fund feasibility studies, market studies, etc. Studies could also include examining whether new features or services would enable the offeror to access climate finance.
  - Finance start-up capital to DSL providers.
  - Finance the development of a minimum viable product.

- **Reaching underserved livestock keepers**
  - Align market incentives for private sector actors to reach traditionally underserved customer segments. This may require regulatory approaches or public financing of specific technologies or platforms.
  - Finance pilots with new customer segments.
  - Identify public-private partnerships or government intervention to reach customers who cannot be reached sustainably by the private sector. This could include bundling DSL into existing government digital platforms and services, such as social support and safety net programmes.

Case study: Blended Finance to Scale Digital Dairy in India

A dairy producer uses an Automatic Milk Collection Unit (AMCU) controlled by an android IoT device. smartAMCU by Stellapps enables IoT-based, real-time acquisition and dissemination of milk procurement data at the collection centres. Photo: Stellapps.

Photo: Stellapps.

Stellapps Technologies provides end-to-end digitised dairy supply chain services for actors across the dairy value chain including cow monitoring and technical advisory for producers to improve productivity, a digital payment platform for dairy cooperatives and processors, an alternative credit scoring system for access to formal finance, milk procurement and cold chain management applications to reduce milk loss, supply chain software solutions, and GHG emissions monitoring.

Stellapps Technologies was incubated in 2011 through the Rural Technology Business Incubator at the Indian Institute of Technology Madras. Stellapps' first tools, smartAMCU and conTrak, digitise milk procurement at milk collection and chilling centres, ensuring quality and reducing waste. In 2019, Stellapps received grant from the Gates Foundation to expand service offerings through the mooON application. The app is tailored for smallholder Indian dairy farmers and is connected to AI-powered pedometers that monitor cattle activity and provide real-time information on animal health and productivity that supports producers and extension professionals with advisory messaging and task alerts. In 2022, IDH Farmfit Fund, public-private impact fund that seeks to de-risk investments for smallholder farming, provided further investment to enable Stellapps to develop the smartFarms app to better reach smallholder producers, particularly women (who make up 83 percent of dairy producers in India), with easy and timely access to digital extension services, quality cattle nutrition, financial services, premium market linkage and other agri-

input services.

Stellapps has mobilised additional private sector investment. They are now in the scale up stage and have reached 3.5 million dairy producers in 17 states of India and digitally trace over 14 million litres of milk per day. Stellapps' business creates a sustainable revenue structure by providing free services to smallholder producers (those with less than ten cows), while generating profit through subscription services from larger producers and other dairy sector actors. This lays the groundwork for India's dairy sector to increase its productivity and traceability, improve livelihoods for dairy sector actors, record and centralise data, and reduce GHG emissions intensity in the dairy sector.

Conclusion

The dual challenges of low productivity and high emissions intensity in the livestock sector in many LMICs are fundamentally linked to a deficit in effective advisory services and verifiable data. The widespread deployment of DSL offers a strategic and underutilised opportunity to address these issues. By providing a cost-effective way to disseminate best practices, DSL can drive significant increases in production efficiency that also drives reduction in emissions intensity and development co-benefits. Crucially, DSL also generate the essential data needed for robust GHG accounting, which is critical for strengthening national climate policies and unlocking access to climate finance. This roadmap provides a clear, actionable framework for governments and IFIs to systematically integrate DSL into their investment portfolios. By following these pathways, stakeholders can not only support key climate and development goals but also build the foundational MRV systems necessary for a more sustainable and resilient future for the livestock sector in LMICs.

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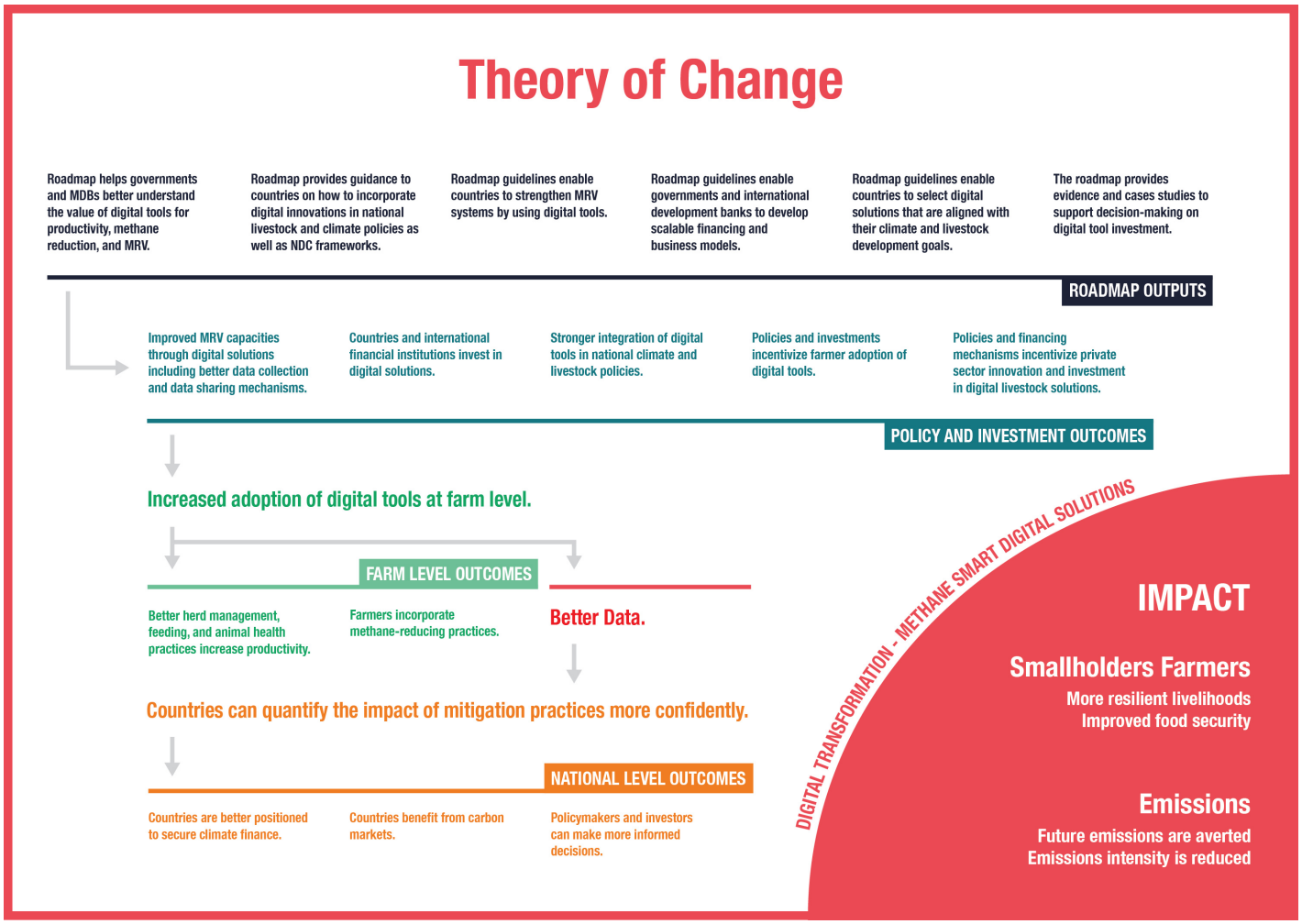
Appendices

Theory of Change

The following diagram outlines the Theory of Change for the Solutions Group on Digital Services for Livestock Methane Management.



Linkages

The four pathways are interlinked in several ways, with each one supporting and strengthening the others through shared data, coordinated investments, and joint capacity building efforts. The following chart highlights these interlinkages.

	 Pathway 1 Digital Public Infrastructure	 Pathway 2 National Policies	 Pathway 3 Livestock Data Ecosystems	 Pathway 4 Private sector investment
Interoperability and data transparency are key for Pathway 1 and Pathway 2, and constitutes a significant part of Pathway 3.	✓	✓	✓	
DSL landscape in Pathway 4 is closely linked to the mapping DSL ecosystem in Pathway 2		✓		✓
Scaling DSL across the livestock sector (Pathway 4) would lay foundation for improved MRV (Pathway 3), which, in turn, facilitates integrating DSL into national policies and investments (Pathway 2)		✓	✓	✓
Data from registries (Pathway 1) can compose a significant part of MRV system (Pathway 3)	✓		✓	
Coordinated investments in livestock data ecosystems (Pathway 2) can address challenges around reporting capacities with improved MRV systems (Pathway 3)		✓	✓	
Mapping existing data ecosystem in Pathway 2 and Pathway 3 provide for common goals		✓	✓	
Capacity development is a shared strategy across all four pathways	✓	✓	✓	✓

Acknowledgments

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The LD4D Solutions Group on Digital Services for Livestock Methane Management brings together decision-makers and experts to generate evidence-based insights that help livestock development projects access climate finance. The group aims to enhance the uptake of digital services to help reduce livestock sector methane emissions and emissions intensity in low-and middle-income countries.

About LD4D: Livestock Data for Decisions (LD4D) is a worldwide community of over 2000 members and partners working to improve livestock data and evidence in low- and middle-income countries. LD4D aims to support the transition to more sustainable and inclusive livestock systems by mobilising livestock data and evidence for better policies, investments, and strategies. LD4D is convened by SEBI-Livestock, the Centre for Supporting Evidence Based Interventions in Livestock, which is hosted by the Royal (Dick)

School of Veterinary Studies, University of Edinburgh. Learn more at livestockdata.org

About CCAC: The Climate and Clean Air Coalition (CCAC) is a voluntary partnership of over 200 governments, intergovernmental organizations, and non-governmental organizations founded in 2012, and convened within the United Nations Environment Programme (UNEP). Collectively and individually, partners who join the Climate and Clean Air Coalition are working to reduce powerful but short-lived climate pollutants (SLCPs) – methane, black carbon, hydrofluorocarbons (HFCs), and tropospheric ozone – that drive both climate change and air pollution. This solutions group builds on a 2024 report on the Role of Digital (Extension) Services for Livestock on Tackling Methane Emissions, prepared by the CCAC Technology and Economic Assessment Panel (TEAP). Learn more at ccacoalition.org

We welcome your feedback. Please contact us with any feedback or suggestions. If you are interested in supporting our work and exploring partnership opportunities, please visit livestockdata.org/partnership.

Endnotes

1. Several studies have demonstrated that digital agricultural advisory services can be more cost-effective than traditional methods in LMICs. For example, a study of text-message-based agricultural extension programmes in Kenya and Rwanda found that these programmes were "extremely cost-effective due to their low delivery costs." The study estimated a benefit-cost ratio of about 46:1 when operated at a large scale (Fabregas and Kremer, 2024). Further, a study in India found that use of personalised digital extension services is positively and significantly associated with input intensity, production diversity, crop productivity, and crop income (Rajkhowa and Qaim, 2021).
2. AgDataHubs are national agricultural and climate data centers designed to integrate meteorological data into agricultural decision-making. In Mali, an AgDataHub was developed as part of Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA). These hubs aim to centralise agricultural and climate data, providing simplified access for various users. They integrate data from multiple sources to deliver climate insights and digital advisories supporting climate-resilient agriculture
3. MRV is a structured process that ensures that GHG emissions and mitigation actions are accurately quantified, transparently reported, and independently verified for reliability and consistency, using standard methods and tools that are relevant for the livestock sector in a given country context. This process provides an evidence base for emission estimates and supports policy and market mechanisms. It also enables producers, producer organizations and governments to demonstrate progress in reducing GHG emissions, and IFIs to track the impact of their investments on GHG emissions and to strengthen national policy frameworks.