Assessment of smart farming solutions for smallholders in low and middle-income countries

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Digital Agri Hub strives to build a sustainable digital agriculture (D4Ag) landscape towards agriculture transformation in low- and middle-income countries (LMICs).

Digital Agri Hub is developed under a partnership between Wageningen University & Research (WUR), the GSMA AgriTech Programme, Grameen Foundation and the Netherlands Advisory Board on impact investing (NAB).

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Authors:
Panos Loukos, Insights Director, GSMA Mobile for Development
Leslie Arathoon, Telecommunications Consultant, Emerging Markets

External contributors:
Sander Janssen, Wageningen University & Research
Jaclyn Bolt, Wageningen University & Research

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Executive summary

Executive summary

Smart farming refers to the use of on-farm and remote sensors to generate and transmit data about a specific crop, animal or practice to enable the mechanisation and automation of on-farm practices and achieve more efficient, high-quality and sustainable production of agricultural goods. Smart farming solutions often rely on connectivity between Internet of Things (IoT)-enabled devices to optimise production processes and growth conditions while minimising costs and optimising resource use.

Smart farming solutions can play an important role in helping smallholder farmers in low- and middle-income countries (LMICs) increase their productivity and resilience to disaster by opening access to assets and mechanisation, optimising the use of inputs, labour and natural resources and reducing crop and animal losses and waste. Although smart farming is one of the more recent digital agriculture use cases to emerge in LMICs, early results appear promising.

Digitalisation for agriculture (D4Ag) providers[1] are reporting several benefits from the use of smart farming tools, including shorter production cycles, reduced land preparation and labour costs, lower use of inputs and scarce resources like water, higher yields, less spoilage and fewer losses from pests and diseases. Still, smart farming solution providers face a variety of challenges to achieving scale, including low digital and technical literacy among smallholders, the high cost of devices, the high cost of connectivity and ongoing services and the lack of mobile and IoT network coverage in rural areas.

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1   According to the Technical Centre for Agricultural and Rural Cooperation (CTA), Digitalisation for Agriculture (D4Ag) is the use of digital technologies, innovations and data to transform business models and practices across the agricultural value chain and address bottlenecks in, among other things, productivity, post-harvest handling, market access, finance and supply chain management to increase incomes for smallholder farmers, improve food and nutrition security, build climate resilience and expand inclusion of youth and women. CTA. (2021). *The Digitalisation of African Agriculture Report, 2018–2019*.

Executive summary

The Digital Agri Hub team examined more than 70 smart farming solutions being implemented in LMICs around the world. The solutions cover three sub-use cases, including smart crop management, smart livestock management[2] and mechanisation access services.

Six key trends were identified from the team's review:

1 **Smart farming solutions have had a strong focus on high-end, capital-intensive crops like horticulture, aquaculture and livestock,** in contrast to other digital agriculture solutions where there is a stronger focus on cash crops.

2 **Smart farming services require a robust technical background and strong digital services know-how.** As a result, there are fewer traditional digital agriculture service players (such as mobile operators, NGOs and governments) playing a leading role in the roll-out of smart farming solutions.

3 Although achieving scale has been elusive for most smart farming solution providers to date, **aquaculture management service solution providers have enjoyed some early successes in expanding their user numbers and attracting funding from investors.**

4 Smart farming solution providers focused on smallholder farmers are pivoting away from pitching the technology itself (smart sensors, smart greenhouses, smart irrigation systems, etc.) to **pitching platforms and solutions that solve specific smallholder problems.**

5 **Smart farming solutions are often bundled with e-commerce platforms** that connect farmers to input suppliers, traders and buyers to help them find markets for their increased yields.

6 **Smart farming solutions have struggled to make inroads with female farmers** given the nascent stage of most smart farming companies. In the early stages, D4Ag providers have focused on scale without necessarily taking a gender lens approach.

2   Smart livestock management refers to the smart monitoring of livestock, beehives and seafood. See page 33 for a more detailed definition.

Executive summary

Our research also identified six main business models being implemented by smart farming solution providers in LMICs. These are not mutually exclusive as D4Ag providers may rely on different models to target different customer segments. For example, a D4Ag provider may rely on upfront purchases for their business-to-business (B2B) channel but on pay-as-you-go (PAYG) for their business-to-consumer (B2C) channel.

To date, the smart farming services that have had the most success achieving scale are those that rely on the PAYG or smart farming-as-a-service models. These business models lower the barrier to entry for smallholder farmers while creating an ongoing relationship that allows the D4Ag provider to maintain control of the farmer relationship and upsell new services over time. Companies such as eFishery and SunCulture have successfully adopted these models to increase their user numbers and attract the attention of investors. To successfully execute these models, however, D4Ag companies must either have sufficient funding to extend financing to smallholders themselves or they must team up with a financial institution able to provide financing.
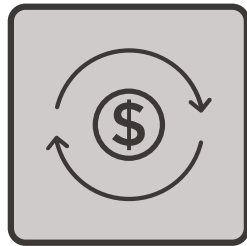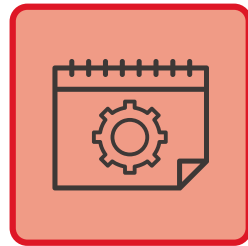
Upfront purchase or asset transfer	Pay-as-you-go (PAYG)	Smart farming-as-a-service/subscription	Freemium or tiered	Service bundling	Data or insights monetisation

Executive summary

Given the nascent stage of the smart farming opportunity in LMICs, investors, donors and other industry stakeholders will need to take several steps before deciding to invest in a smart farming venture. Our research has resulted in the following recommendations for ecosystem players seeking to invest in smart farming solutions in LMICs:

1 Prioritise higher-margin value chains for market entry, such as fresh produce, aquaculture and livestock. These value chains give smallholder farmers slightly more room to invest in new technologies than cash crops, which tend to have very low margins and prices are beyond their control.

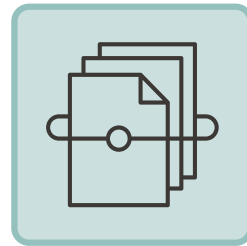**2 Consider the characteristics of a country before deciding on market entry.** Pay particular attention to the regulatory environment, available network infrastructure, the competitive environment and the maturity of the targeted value chains.

3 Prioritise the right partnerships. Smart farming solutions tend to be more complex than other digital agriculture solutions and, therefore, often require the participation of other ecosystem players. Look to other D4Ag providers to enhance the service offering, to agribusinesses and cooperatives to help aggregate demand, to financial service providers (FSPs) to facilitate financing or identify new target segments (for the monetisation of data), to mobile network operators (MNOs) for network access and client relationships and to asset or hardware manufacturers to help reduce the cost of the hardware by creating scale.

4 Take a long view. Patient capital from early investors will make it easier for D4Ag providers with smart farming solutions to attract additional investors and scale their business. D4Ag players will need to spend time educating investors about the potential of smart farming solutions.

5 Ensure farmers are involved in the design of smart farming solutions. Solutions must solve challenges that smallholder farmers face in their daily lives, not those that governments, investors or other stakeholders perceive they face.

6 Understand the total cost of the solution being offered and how that compares with a smallholder farmer's ability to pay for the solution. This includes understanding the full cost of implementing the technology (e.g. setting up the sensors, installing gateways, etc.) as well as the ongoing support (e.g. access to the platform, data connectivity, etc.).

7 Offer more than just data. It is critical, particularly in the context of smallholder farming, that D4Ag solution providers offer more than just the data generated from their smart farming technology. They must translate that data into specific recommendations and, eventually, automated actions. They must also endeavor to offer holistic solutions that help farmers solve a multitude of challenges, not just one specific challenge.

1 **Introduction**

Smart farming solutions can help smallholder farmers become more productive and resilient

Smallholder farmers, defined as farmers operating on two hectares of land or less, currently manage around a quarter of the world's cropland and produce around a third of its food.[3] In some countries, their contribution to food production can be as high as 80 per cent.[4] Increasing the productivity of smallholders is critical, not only to meet the expected increase in demand for food, but also to help lift rural populations out of poverty.

Productivity gains in LMICs can be achieved in different ways, from more efficient use of fertilisers and higher quality inputs, to the use of irrigation systems, cold storage and machinery, to more efficient crop monitoring and waste reduction. For example, the Food and Agriculture Organization of the United Nations (FAO) estimates that farmers using irrigation systems are twice as productive per unit of land as those relying on rainfed agricultural practices alone.[5]

Smart farming solutions can power the transformation of the agriculture sector and assist in the professionalisation of smallholder farming by automating decision-making at the farm level. They can help smallholder farmers in LMICs increase their productivity and disaster resilience by opening access to assets and mechanisation, optimising the use of inputs, labour and natural resources and reducing crop and animal losses and waste.

> Increasing the productivity of smallholder farming is a crucial step in countries transitioning from poverty to middle-incomes. Raising the output and incomes of smallholder farmers should be an important focus even if they produce [less of the global food than previously thought]. This is because most of the world's farms are smallholders, and they are some of the poorest people in the world.
>
> **Hannah Ritchie, University of Oxford[6]**

3   Ritchie, H. (6 August 2021). "Smallholders produce one-third of the world's food, less than half of what many headlines claim". *Our World in Data*. University of Oxford. Available at: https://ourworldindata.org/smallholder-food-production.

4   FAO. (2021). *Small family farmers produce a third of the world's food*. Available at: www.fao.org/news/story/en/item/1395127/icode/.

5   FAO. (2017). *Water for Sustainable Food and Agriculture: A Report Produced for the G20 Presidency of Germany*. Available at: www.fao.org/3/i7959e/i7959e.pdf.

6   Ritchie, H. (6 August 2021). "Smallholders produce one-third of the world's food, less than half of what many headlines claim". *Our World in Data*. University of Oxford. Available at: https://ourworldindata.org/smallholder-food-production.

The global challenge of productivity: Rising demand for food will require a 60 to 70 per cent increase in production by 2050

By 2050, the world's population will reach 9.8 billion, a more than two billion-person increase over 2021 (7.6 billion).[7] Most of these people will be living in LMICs, primarily in Africa, South Asia and Southeast Asia. Population growth, combined with significant shifts in food consumption driven by rising urbanisation and incomes mean that food production will need to increase by 60 to 70 per cent by 2050 to meet demand.[8] For some categories of food, production will need to increase by more than 100 per cent to meet expected demand (see Figure 1). This increase in production will be taking place in the context of a changing environment and added stresses on scarce resources like water and arable land. This is particularly true in LMICs where productivity levels are significantly lower than those in more developed markets and where smallholder farmers play a major role in food production.

Figure 1

Production increases needed in different value chains by 2050 to meet expected demand

| 133%[9] | 73%[10] | 58%[11] | 120%[12] | 50%–163%[13] |

Sources: FAO, World Resources Institute, Watt Poultry, Conservation International

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7   United Nations. (2021). "*World population projected to reach 9.8 billion in 2050 and 11.2 billion in 2100 – says UN*".
    Available at: www.un.org/en/desa/world-population-projected-reach-98-billion-2050-and-112-billion-2100.

8   FAO. (2017). *Water for Sustainable Food and Agriculture: A Report Produced for the G20 Presidency of Germany*. Available at: www.fao.org/3/i7959e/i7959e.pdf.

9   World Resources Institute. (2014). *Farmed Fish Production Must More than Double by 2050, New Analysis Finds*.
    Available at: www.wri.org/news/release-farmed-fish-production-must-more-double-2050-new-analysis-finds.

10 FAO. (2011). *Major gains in efficiency of livestock systems needed*. Available at: www.fao.org/news/story/en/item/116937/icode/.

11 Ibid.

12 Watt Poultry. (2014). *World poultry production expected to more than double by 2050*. Available at: www.wattagnet.com/articles/19085-world-poultry-production-expected-to-more-than-double-by-2050.

13 Conservation International. (2016). *Coffee in the 21st Century*. Available at: www.conservation.org/docs/default-source/publication-pdfs/ci-coffee-report.pdf.
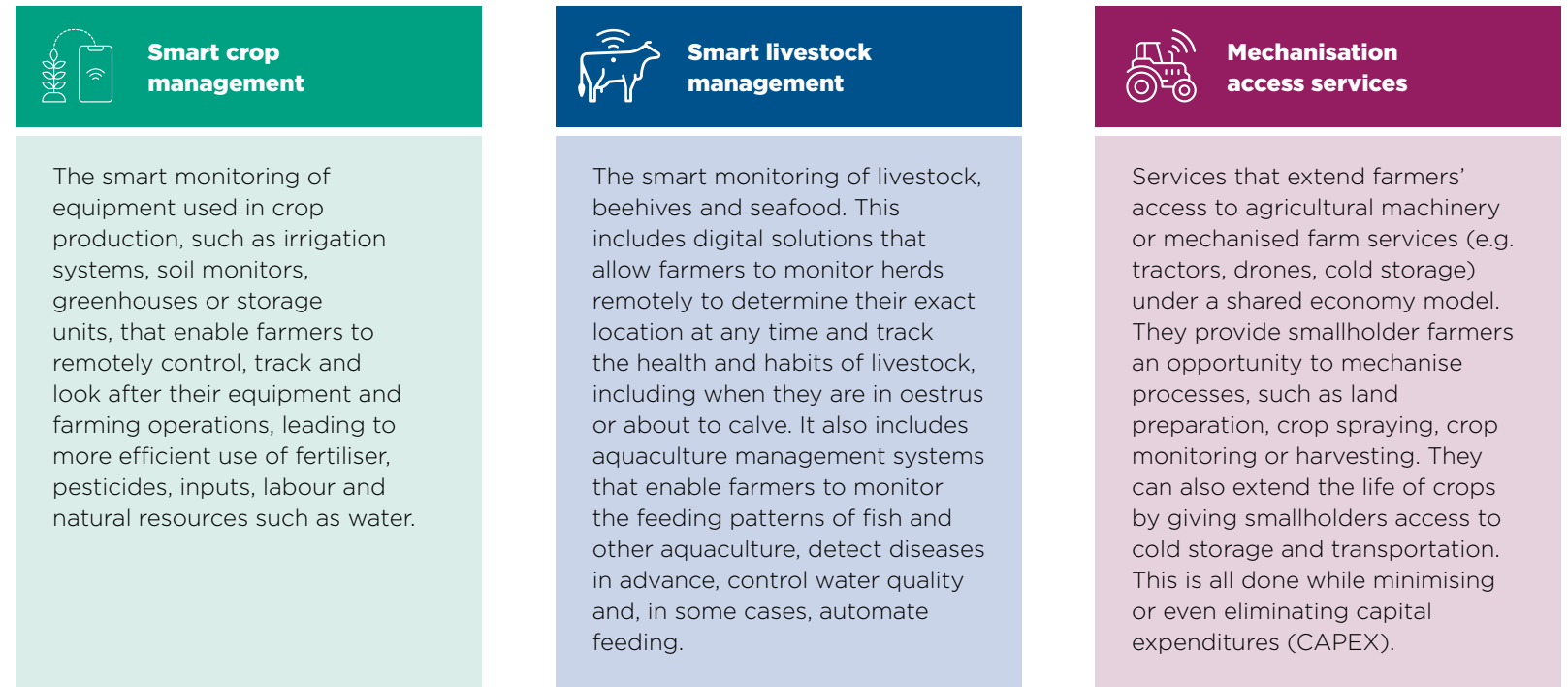
The Digital Agri Hub team has identified three smart farming sub-use cases applicable in LMICs

Smart farming refers to the use of on-farm and remote sensors to generate and transmit data about a specific crop, animal or practice to enable the mechanisation and automation of on-farm practices and achieve more efficient, high-quality and sustainable production of agricultural goods. Smart farming solutions often rely on connectivity between IoT-enabled devices to optimise production processes and growth conditions while minimising costs and optimising resource use.[14] Within the context of LMICs, the Digital Agri Hub has identified three main sub-use cases, as outlined in Figure 2.

Figure 2

Smart farming sub-use cases

Smart crop management

The smart monitoring of equipment used in crop production, such as irrigation systems, soil monitors, greenhouses or storage units, that enable farmers to remotely control, track and look after their equipment and farming operations, leading to more efficient use of fertiliser, pesticides, inputs, labour and natural resources such as water.

Smart livestock management

The smart monitoring of livestock, beehives and seafood. This includes digital solutions that allow farmers to monitor herds remotely to determine their exact location at any time and track the health and habits of livestock, including when they are in oestrus or about to calve. It also includes aquaculture management systems that enable farmers to monitor the feeding patterns of fish and other aquaculture, detect diseases in advance, control water quality and, in some cases, automate feeding.

Mechanisation access services

Services that extend farmers' access to agricultural machinery or mechanised farm services (e.g. tractors, drones, cold storage) under a shared economy model. They provide smallholder farmers an opportunity to mechanise processes, such as land preparation, crop spraying, crop monitoring or harvesting. They can also extend the life of crops by giving smallholders access to cold storage and transportation. This is all done while minimising or even eliminating capital expenditures (CAPEX).

Source: GSMA

14   GSMA. (2020). *Digital Agriculture Maps: 2020 State of the Sector in Low and Middle-Income Countries.*
     Available at: www.gsma.com/r/wp-content/uploads/2020/09/GSMA-Agritech-Digital-Agriculture-Maps.pdf.

This report explores the emergence of smart farming solutions in LMICs and identifies opportunities to scale these solutions

This assessment of the smart farming opportunity in LMICs is the first in a series of reports produced for the Digital Agri Hub[15] that highlight innovations supporting climate and disaster resilience, inclusivity and increased productivity and well-being. The Digital Agri Hub is a partnership between Wageningen University & Research (WUR), the GSMA AgriTech programme, Grameen Foundation and the Netherlands Advisory Board on Impact Investing (NAB). The Digital Agri Hub aims to identify, test and disseminate D4Ag technologies and business model innovations to help guide investments towards agricultural transformation in LMICs.

The analysis presented in this report shines a light on smart farming solutions being commercialised in LMICs in the context of small-scale farming in rural areas. There is a strong focus on how smart farming solutions can enable smallholder farmers to access assets and mechanisation, increase labour efficiency, improve productivity and resilience to climate change, promote the inclusion of groups typically left behind (including women and youth), increase incomes and facilitate smallholder access to credit and insurance products.

The Digital Agri Hub team focused the research on answering the following questions:

1 What are the leading smart farming solutions available in LMICs?

2 What smallholder challenges do these smart farming solutions address?

3 What are the enabling factors and challenges impacting the growth of technology-enabled smart farming solutions?

4 What use cases do the various smart farming solutions support and how do they contribute to climate and disaster resilience, inclusivity and increased productivity and well-being?

5 What operational and business models for smart farming are emerging and how can smart farming solutions achieve scale?

6 What technologies are supporting the implementation of smart farming solutions?

7 How are investors perceiving the smart farming opportunity?

15   Digital Agri Hub. (2021). Available at: https://digitalagrihub.org/web/guest/home.

Key audiences

The Digital Agri Hub prepared this report to provide supply-side solution providers, such as D4Ag providers and MNOs, as well as the investors and donors that support them, with insights into the smart farming opportunity in LMICs. Other sector players, such as agribusinesses, cooperatives, farmer groups, mobile money providers (MMPs), FSPs, governments and NGOs, can also benefit from the insights of this study.

Supply-side actors, such as **D4Ag providers** and **MNOs**, will gain insights into the deployment of smart farming solutions in LMICs, as well as the business and operational models being leveraged to scale them. The report offers examples of innovations that have been deployed to date and recommendations for how these and future solutions can be scaled.

Impact investors and donors will gain insights into how to de-risk investment in smart farming innovations in LMICs. The report highlights different business and operational models that have been implemented in smallholder farming contexts in LMICs and offers recommendations for future interventions.

About the framework

The D4Ag solution assessment framework guided the research process and informed which companies were targeted for inclusion in this report (see Figure 3). The Digital Agri Hub team prioritised D4Ag providers that are operating in LMICs and targeting smallholder farmers whose solutions met at least one of the framework's three criteria: (1) climate and disaster resilience, (2) inclusive (e.g. accessible to all genders, abilities and ages) and (3) increased productivity and/or well-being.

The team also prioritised solutions that were deemed sensible in the context of smallholder farming in LMICs. While we encountered some solutions that have had success with large-scale farmers in LMICs, they have struggled to make inroads with smallholder farmers either because they are too complicated to use, too expensive, too easily stolen or have always-on connectivity requirements. These solutions were not included in the study. We did opt to include some solutions that, while not yet proven in the marketplace, could be potential game-changers given the innovative model or the positive outcomes observed during pilot testing. While the focus was primarily on commercially available solutions, we have included a few pre-launch solutions or solutions that are still in pilot mode given their potential.

Figure 3

D4Ag solution assessment framework
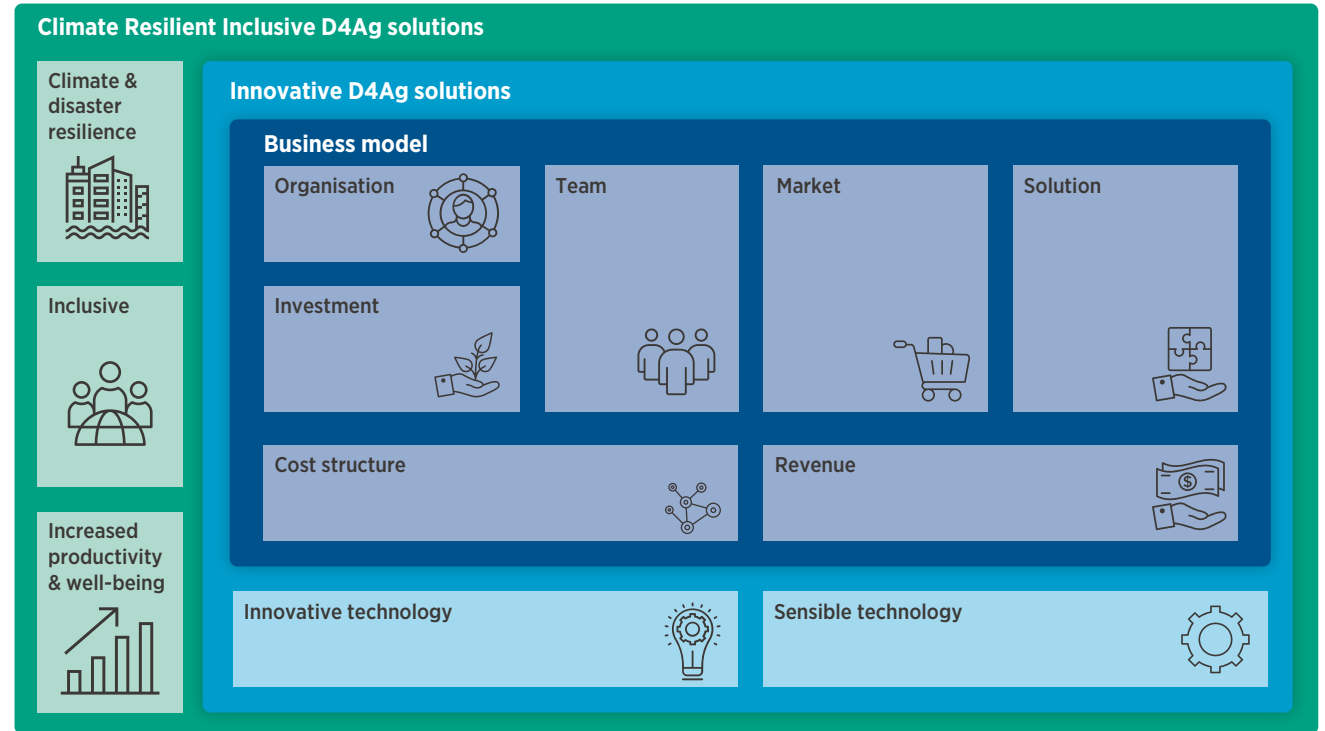
Source: Digital Agri Hub

About the research

Desk research

- Consulted more than 100 reports, including internal GSMA reports and toolkits, third-party reports, academic journals, press releases, case studies, financial statements and other sources.

- Accessed internal databases tracking digital agriculture solutions and IoT connections, among others.

- Used external databases, including World Bank Data, FAOSTAT, United Nations and national statistics agencies for country-level IoT market sizing.

Stakeholder interviews

- Conducted in-depth interviews with more than 30 agriculture sector stakeholders between September and December 2021, including D4Ag providers (e.g. AquaRech, Inspira Farms, eFishery, Synnefa, TROTRO Tractor), MNOs (e.g. Dialog, Orange, Telefónica), donors and investors (e.g. Heifer International, USAID, Shell Foundation).

- The team targeted smart farming solutions across various use cases and geographies to obtain a broad perspective.

About the structure of this report

The next section of the report (**Section 2**) provides a landscape assessment of the smart farming market in LMICs. It begins by outlining how smart farming solutions can help at every stage of the agricultural cycle. It then highlights some of the key enablers for the development of smart farming solutions, as well as some of the main obstacles that smart farming solution providers have faced in deploying smart farming solutions in LMICs. For each of the three sub-use cases defined on page 13, there is a more detailed definition, a review of different solution providers and an assessment of the main benefits of each type of solution for smallholders. This section concludes by highlighting some of the main trends observed through an analysis of smart farming deployments in LMICs to date.

Section 3 provides a high-level assessment of the overall opportunity for small farming connections in selected markets under an optimistic scenario.

Section 4 examines the role of technology in the deployment of smart farming solutions. As this section makes clear, there is no one-size-fits-all approach to deploying a smart farming solution. The technology employed and network architecture chosen depend on a variety of supply- and demand-side factors at play in a market. The objective of this section is to help investors critically assess smart farming solutions and the path suggested by D4Ag providers.

Section 5 presents an analysis of the various business models identified in a review of dozens of smart farming solutions being deployed in LMICs. Some of the key advantages and disadvantages of each model are outlined to help investors and D4Ag service providers identify the merits of implementing each business model in the context of their own markets.

The report concludes (**Section 6**) by outlining some of the key considerations smart farming ecosystem stakeholders should be aware of when deploying smart farming solutions. Some recommendations are also provided for ecosystem stakeholders to help them reduce the risks of deploying smart farming solutions in LMICs.

About the structure of this report

Sections 2 and 4, in particular, make heavy use of case studies to illustrate the benefits, opportunities and challenges associated with different types of solutions, use cases or business models. Each use case includes icons identifying the use case, business model and D4Ag framework priorities met by the solution, if applicable (see Figure 4). Where the solution is not yet commercially available, the business model icon may have been omitted. It should be noted that much of the data provided in the case studies was reported by the D4Ag providers themselves, and there was not always the opportunity for it to be independently verified by a third party. This is typical of nascent solutions in the early years of implementation.

Figure 4

Icons used in report case studies

USE CASE ICONS

Smart crop management

Smart livestock management

Mechanisation access services

D4AG PRIORITIES

Increased productivity & well-being

Climate & disaster resilience

Inclusive

BUSINESS MODEL ICONS

Upfront purchase or asset transfer

Pay-as-you-go (PAYG)

Smart farming-as-a-service/ subscription

Freemium or tiered

Service bundling

Data or insights monetisation

2 Smart farming landscaping and trend analysis

Smart farming solutions can benefit smallholder farmers at every stage of the agricultural cycle
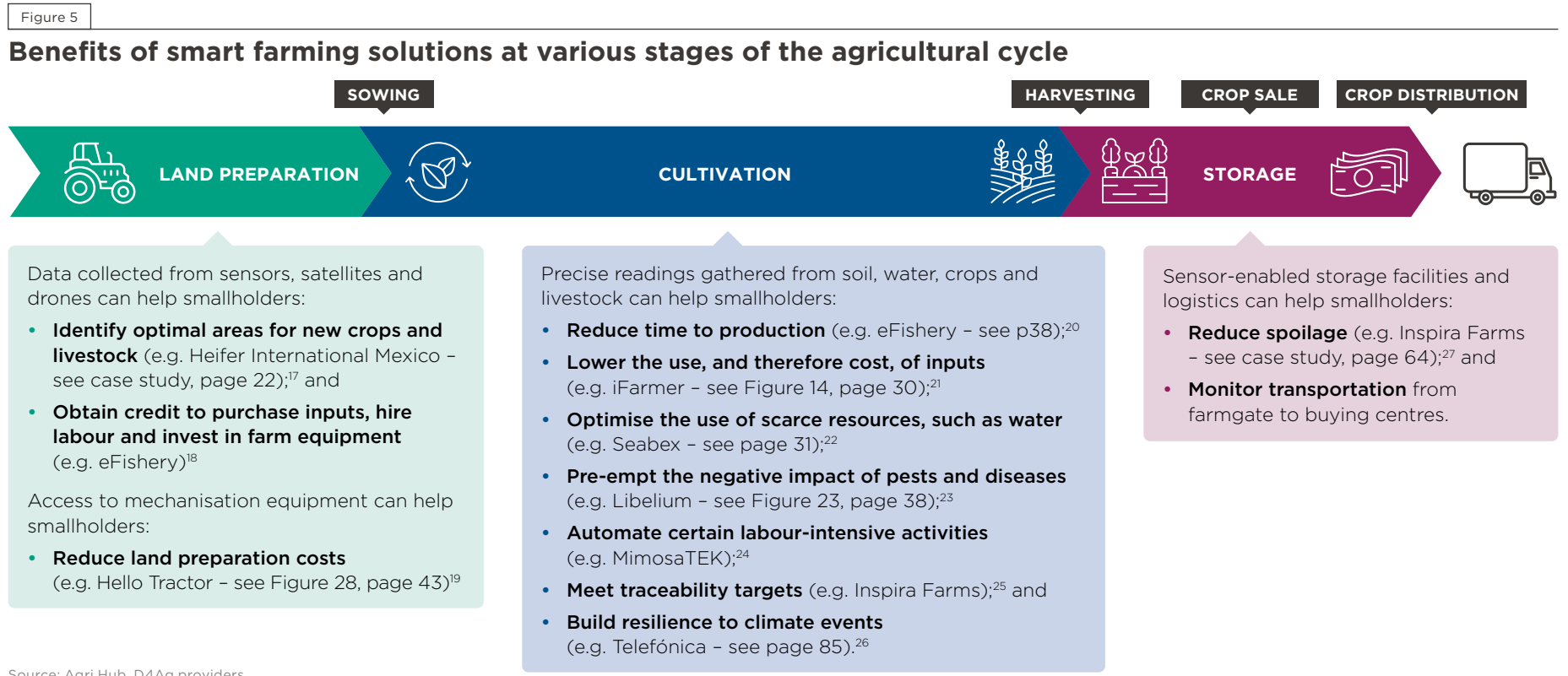
By using data collected from sensors, satellites or drones – and then applying analytics tools to that data – smart farming solutions can predict future behaviour. This, in turn, can lead farmers to take actions that minimise negative outcomes (e.g. crop diseases, fish deaths) and maximise positive results (e.g. ensure cow insemination periods are not missed, optimise irrigation and fertilisation schedules). Most solutions identified here are used in the cultivation stage, given the focus of smart farming on increasing productivity through better access to assets (see Figure 5).[16]

Figure 5

Benefits of smart farming solutions at various stages of the agricultural cycle

SOWING · HARVESTING · CROP SALE · CROP DISTRIBUTION

LAND PREPARATION · CULTIVATION · STORAGE

Data collected from sensors, satellites and drones can help smallholders:

- **Identify optimal areas for new crops and livestock** (e.g. Heifer International Mexico – see case study, page 22);[17] and
- **Obtain credit to purchase inputs, hire labour and invest in farm equipment** (e.g. eFishery)[18]

Access to mechanisation equipment can help smallholders:

- **Reduce land preparation costs** (e.g. Hello Tractor – see Figure 28, page 43)[19]

Precise readings gathered from soil, water, crops and livestock can help smallholders:

- **Reduce time to production** (e.g. eFishery – see p38;[20]
- **Lower the use, and therefore cost, of inputs** (e.g. iFarmer – see Figure 14, page 30);[21]
- **Optimise the use of scarce resources, such as water** (e.g. Seabex – see page 31);[22]
- **Pre-empt the negative impact of pests and diseases** (e.g. Libelium – see Figure 23, page 38);[23]
- **Automate certain labour-intensive activities** (e.g. MimosaTEK);[24]
- **Meet traceability targets** (e.g. Inspira Farms);[25] and
- **Build resilience to climate events** (e.g. Telefónica – see page 85).[26]

Sensor-enabled storage facilities and logistics can help smallholders:

- **Reduce spoilage** (e.g. Inspira Farms – see case study, page 64);[27] and
- **Monitor transportation** from farmgate to buying centres.

Source: Agri Hub, D4Ag providers

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16 Assets in this context refers to both fixed assets (e.g. tractors, drones, threshers, cold storage facilities, irrigation systems) as well as biological assets (e.g. livestock, beehives).

17 Heifer International interview (October 2021).

18 eFishery interview (October 2021).

19 OPEC Fund. (2019). *Big help for Africa's smallholder farmers*. Available at: https://opecfund.org/news/big-help-for-africa-s-smallholder-farmers.

20 eFishery interview (October 2021).

21 iFarmer interview (September 2021).

22 Seabex interview (October 2021).

23 Libelium. (2016). *Fish farm monitoring in Vietnam by controlling water quality in ponds and tanks*. Available at: https://www.libelium.com/libeliumworld/success-stories/fish-farm-monitoring-in-vietnam-by-controlling-water-quality-in-ponds-and-tanks/.

24 MimosaTEK Interview (September 2021).

25 Inspira Farms Interview (October 2021).

26 Telefónica. (2021). *Smart Agro Perú: Una Alianza De Telefónica, FAO y Brasil, Contribuyendo para +Algodón*. Available at: https://iot.telefonica.com/es/whats-new/news/smart-agro-per%C3%BA-una-alianza-de-telef%C3%B3nica-fao-y-brasil-contribuyendo-para-plusalgod%C3%B3n/.

27 Inspira Farms interview (October 2021).

Heifer International Mexico used drones to help smallholder farmers during land preparation and cultivation

CASE STUDY

Heifer International has been working in Mexico since 1977, supporting around 373,000 smallholder farmers across four states (Chiapas, Yucatán, Oaxaca and Puebla).[28] Heifer International's work in Mexico focuses on the livestock, poultry coffee, honey, corn and agave value chains. Between 2017 and 2020, the Heifer International team worked on a pilot to assess the impact of drones on their interventions in Mexico. Using images captured by a Phantom 3 drone (see Figure 6), extension officers were able to advise smallholder farmers on optimal locations for new apiaries or agave plantings. For example, images from a drone could show a farmer that the location selected for a new apiary was in close proximity to a chili pepper farm that used pesticides, which would have made it difficult for the honey farmer to meet traceability requirements.[29] Images captured by the drones also alerted farmers to potential pest infestations, which historically have caused crop losses of up to 40 per cent, and to the first signs of flowering, which can ensure harvesting takes place at the appropriate time.[30]

Figure 6

Phantom 3 drone

Source: DJI

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28 Heifer International Mexico. Available at: https://www.heifer.org/about-us/where-we-work/mexico.html.
29 Heifer International Mexico interview (October 2021).
30 Ibid.

# Key enablers of successful smart farming solutions in LMICs

Based on interviews with D4Ag providers in LMICs and a review of dozens of relevant studies and articles, we were able to identify seven key enablers that lead to more wide-scale adoption of smart farming technologies. For example, a country with a rising middle class, widespread use of mobile money services, a regulatory environment that promotes the use of mechanisation assets and has few restrictions on imports, domestic assembly capabilities and widespread mobile coverage in rural areas, will likely see much higher adoption of smart farming solutions than countries where these enabling forces are weaker.

Most services require **mobile coverage** and **internet connectivity, such as that provided by licensed low power wide area (LPWA) IoT networks,** particularly in rural areas. In the absence of widespread coverage, D4Ag providers must rely on non-licensed alternatives like Sigfox and LoRa, Wi-Fi, Zigbee or even TV white space.

Importing sensors, gateways, smart greenhouses, smart aquaculture feeders and other necessary hardware can be expensive. **Low-cost domestic assembly capabilities** can help lower the cost of devices, making solutions more affordable for smallholders.
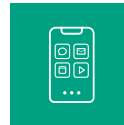
Many remote equipment monitoring solutions require farmers to own **smartphone devices** to manage the platform, although some, with limited features, can be managed through the use of a USSD code or SMS.
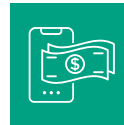
Many mechanisation access services, and some smart crop management solutions, rely on the PAYG model.[31] This model depends on **widespread use of mobile money services** in the community served.

Rising incomes and an expanding middle class in LMICs translates into increased demand for value chains ripe for smart farming interventions, including produce, meat and seafood.

Countries with a **specific value chain mix** are more likely to look to smart farming solutions to improve production. These include more developed livestock and aquaculture markets, as well as more highly structured fresh produce markets.

Many governments in LMICs offer incentives encouraging smallholders to acquire assets that help to boost production or are beneficial to the environment, such as greenhouses, irrigation systems, cold storage facilities and mechanisation equipment (see Figure 53 on page 82). Governments can also play an enabling role by easing import constraints on smart farming hardware and components.

31 Smallholder farmers are gaining access to agricultural assets previously out of reach through PAYG models. PAYG leverages mobile money payments and remote-locking technologies to viably provide assets such as farm equipment, energy grids and irrigation systems to farmers. GSMA. (2021). *Pay-As-You-Go smart assets increase farmers' climate resilience*. Available at: www.gsma.com/mobilefordevelopment/blog/pay-as-you-go-smart-assets-increase-farmers-climate-resilience/.

Key obstacles for D4Ag providers when introducing smart farming solutions

The D4Ag providers interviewed for this report were asked about some of the main obstacles they faced during the roll-out of smart farming solutions. Although some country-specific obstacles emerged, such as regulations preventing the use of drones by smallholder farmers in Nicaragua,[32] the four main obstacles cited by interviewees were the high cost of smart farming hardware and components, limited digital and technical literacy, the high cost of connectivity and ongoing smart farming services and the limited reach of networks in rural areas.

The **high costs of sensors and associated equipment.** Prices for smart farming devices can range anywhere from $200 to $300 for a soil moisture IoT kit all the way to $2,000 to $4,000 for smart feeders, irrigation systems, smart greenhouses or smart cold storage facilities (see Figure 7). Sri Lankan MNO Dialog estimates that their Saru IoT kit costs $200 to $350.[33] This means that it would take farmers one to three agricultural cycles to recoup their investment. This is a relatively long horizon for the average smallholder farmer in Sri Lanka where a typical farmer makes just over $2 a day, according to the CEIC.[34]

As services mature, it will become increasingly important to calculate the cost of smart farming solutions on a per hectare basis to assess the affordability of the solutions. The cost per hectare analysis is beyond the scope of the present study.

Figure 7

Cost of the IoT kit for Smart Agro 4.0 Peru[35]
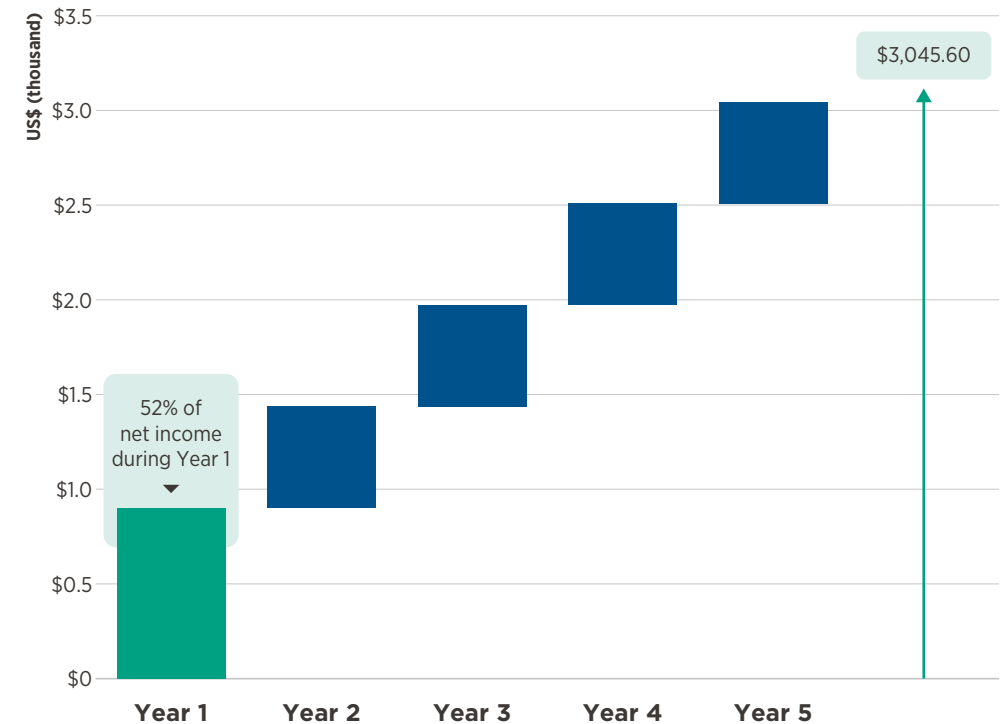
Source: Telefónica

32 Ritter Sport Nicaragua interview (May 2020).

33 Dialog interview (September 2021).

34 CEIC. (2022). Available at: www.ceicdata.com/en/sri-lanka/average-daily-wage.

35 Telefónica. (2021). *Smart Agro Perú: Una Alianza De Telefónica, FAO y Brasil, Contribuyendo para +Algodón*. Available at: https://iot.telefonica.com/es/whats-new/news/smart-agro-per%C3%BA-una-alianza-de-telef%C3%B3nica-fao-y-brasil-contribuyendo-para-plusalgod%C3%B3n/.

Key obstacles for D4Ag providers when introducing smart farming solutions

Limited digital and technical literacy.

For many farmers, particularly those without any formal education or older farmers with limited digital literacy, the use of smart farming solutions can be a challenge. Capacity building ends up being a significant part of the implementation (and cost) of any smart farming solution (see Figure 8).

High cost of connectivity and ongoing services.

Following the purchase of the equipment, a farmer must often pay for ongoing connectivity and access to the service enabled by the smart farming equipment. In most cases, prices for services remain above where most D4Ag solution providers feel they need to be to achieve scale.

Limited network reach in rural areas.

Although coverage through many LMICs now extends to more than 90 per cent of the population, it is often smallholder farmers in rural areas that remain outside the reach of mobile networks. Some smart farming solutions have an offline mode, but most require near constant communication between the sensors in the field, the gateways and the cloud.

Figure 8

TROTRO Tractor's solution for meeting capacity building needs

OBSTACLE

Ghana's TROTRO Tractor found that it was spending much more time than anticipated training farmers on (1) how to use their phone, (2) how to use mobile money, (3) how to use the TROTRO Tractor booking platform and (4) how to operate the tractors. These efforts were taking time away from running and scaling their business.

SOLUTION

TROTRO secured capital from the Alliance for a Green Revolution in Africa (AGRA) to help fund smallholder training on digital financial services, mobile money and the use of mobile phones to make bookings using USSD codes. AGRA is also funding training for tractor operators to help scale the business.[36]

Source: TROTRO Tractor

36   AGRA also works with other smart farming solution providers like Hello Tractor. See Agrilinks. (2021). *Digital Partnerships Help Transform Agripreneurship in Africa*. Available at: www.agrilinks.org/post/digital-partnerships-help-transform-agripreneurship-Africa.
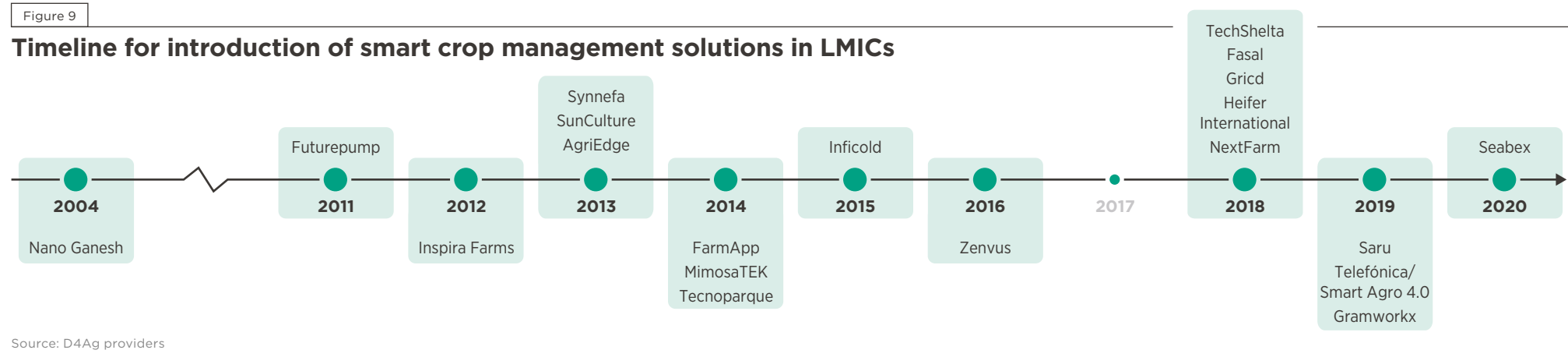
Smart crop management solutions

Smart crop management solutions were among the first smart farming solutions to emerge in LMICs. As early as 2004, India's Nano Ganesh introduced a remote water pump solution for smallholders to reduce the amount of time spent turning irrigation systems on and off (see Figure 9). This early device involved the placement of a 2G mobile phone in a starter panel that was then connected to a pump that could be activated remotely by a farmer through an active call, along with an acknowledgement of the off/on status of both power and pump.[37]

Over the years, the Nano Ganesh solution and other smart crop management solutions have become more sophisticated, and can now be powered by IoT sensors, drones and satellite imagery. Smart crop management solutions have also extended beyond remote management of water pumps to include soil monitoring, crop monitoring, irrigation management and automation, greenhouse management, automatic fertiliser and pesticide application, cold storage management and logistics tracking.

Figure 9

Timeline for introduction of smart crop management solutions in LMICs

Source: D4Ag providers
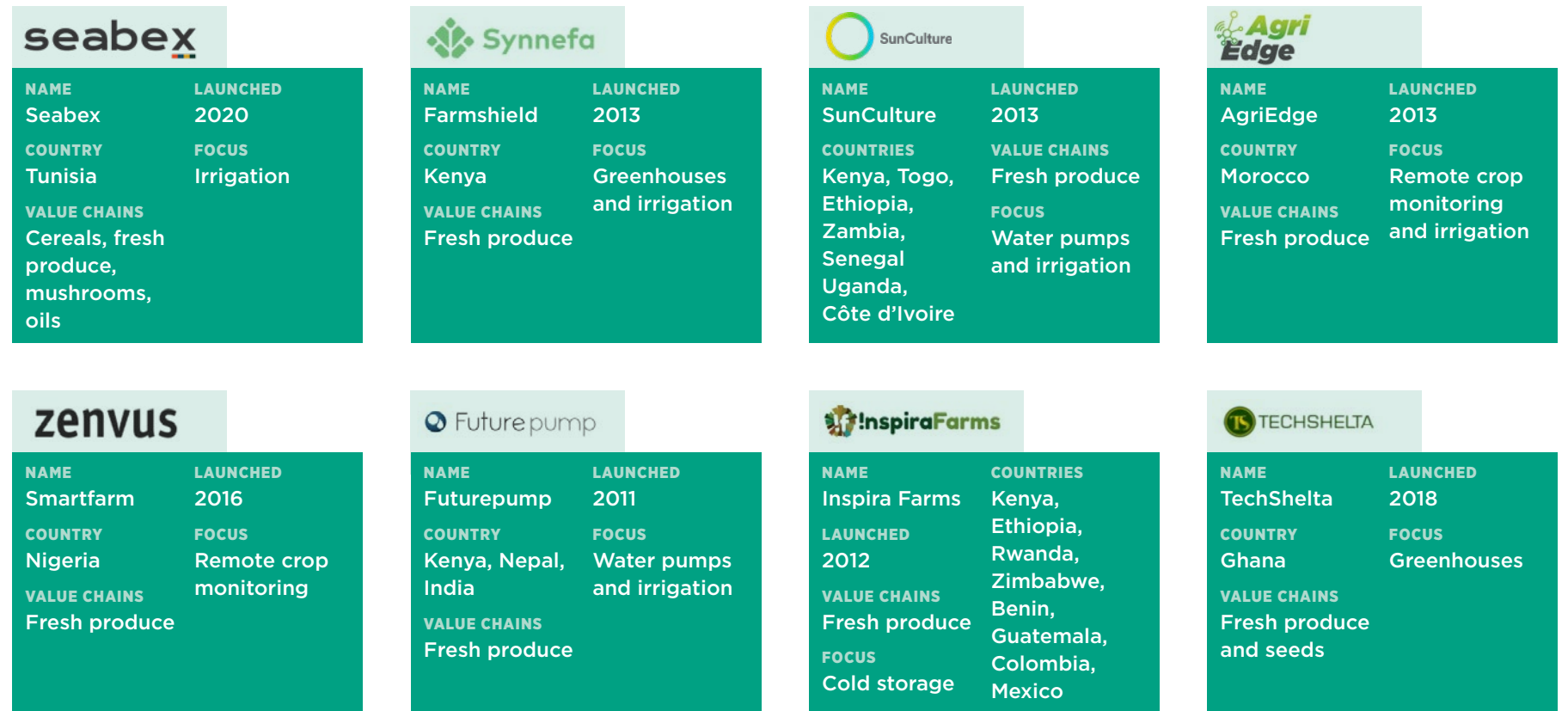
37 Nano Ganesh Interview (November 2021).

Smart crop management solution deployments in Africa and the Middle East

Most of the early smart crop management solutions targeted at smallholder farmers in LMICs were introduced in India or Kenya. South Asia and Africa remain the two top regions for smart crop management solution deployments in LMICs (see Figures 10 and 11). Since 2018, there have been additional service launches in Southeast Asia and Latin America, although many of the initiatives in Latin America are still in the pilot phase and have not yet been commercialised.

Figure 10

Selected smart crop management solutions in Africa and the Middle East, 2021

seabex

NAME	LAUNCHED
Seabex	2020
COUNTRY	FOCUS
Tunisia	Irrigation
VALUE CHAINS	
Cereals, fresh produce, mushrooms, oils	

Synnefa

NAME	LAUNCHED
Farmshield	2013
COUNTRY	FOCUS
Kenya	Greenhouses and irrigation
VALUE CHAINS	
Fresh produce	

SunCulture

NAME	LAUNCHED
SunCulture	2013
COUNTRIES	VALUE CHAINS
Kenya, Togo, Ethiopia, Zambia, Senegal Uganda, Côte d'Ivoire	Fresh produce
	FOCUS
	Water pumps and irrigation

AgriEdge

NAME	LAUNCHED
AgriEdge	2013
COUNTRY	FOCUS
Morocco	Remote crop monitoring and irrigation
VALUE CHAINS	
Fresh produce	

zenvus

NAME	LAUNCHED
Smartfarm	2016
COUNTRY	FOCUS
Nigeria	Remote crop monitoring
VALUE CHAINS	
Fresh produce	

Futurepump

NAME	LAUNCHED
Futurepump	2011
COUNTRY	FOCUS
Kenya, Nepal, India	Water pumps and irrigation
VALUE CHAINS	
Fresh produce	

InspiraFarms

NAME	COUNTRIES
Inspira Farms	Kenya, Ethiopia, Rwanda, Zimbabwe, Benin, Guatemala, Colombia, Mexico
LAUNCHED	
2012	
VALUE CHAINS	
Fresh produce	
FOCUS	
Cold storage	

TECHSHELTA

NAME	LAUNCHED
TechShelta	2018
COUNTRY	FOCUS
Ghana	Greenhouses
VALUE CHAINS	
Fresh produce and seeds	

Note: All services included are commercially available unless noted by the use of the word pilot and/or an end-date in the "Launched" field.
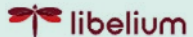Source: D4Ag providers

Smart crop management solution deployments in Asia and Latin America

Figure 11

Selected smart crop management solutions in South and Southeast Asia and Latin America, 2021

Dialog
NAME Saru
LAUNCHED 2019 (pilot)
COUNTRY Sri Lanka
FOCUS Irrigation
VALUE CHAINS Fresh produce, mushrooms

GramworkX
NAME Gramworkx
LAUNCHED 2019
COUNTRY India
FOCUS Irrigation
VALUE CHAINS Fresh produce

mimosaTEK
NAME MimosaTEK
LAUNCHED 2014
COUNTRY Vietnam
FOCUS Irrigation
VALUE CHAINS Fresh produce

HEIFER INTERNATIONAL
NAME Heifer International
LAUNCHED 2018–2020 (pilot)
COUNTRY Mexico
FOCUS Remote crop monitoring
VALUE CHAINS Livestock, bees, agave, coffee

Nano Ganesh
NAME Nano Ganesh
LAUNCHED 2004
COUNTRY India
FOCUS Water pumps and irrigation
VALUE CHAINS Fresh produce

Fasal
NAME Fasal
LAUNCHED 2018
COUNTRY India
FOCUS Irrigation
VALUE CHAINS Fresh produce

ANANKE
NAME ANANKE IoTea
LAUNCHED 2018
COUNTRY Sri Lanka
FOCUS Crop monitoring
VALUE CHAINS Tea

libelium
NAME Tecnoparque
LAUNCHED 2014 (pilot)
COUNTRY Colombia
FOCUS Remote crop monitoring
VALUE CHAINS Fresh produce (bananas)

NextFarm
NAME NextFarm
LAUNCHED 2018
COUNTRIES Vietnam, Myanmar, Cambodia
FOCUS Irrigation and crop monitoring
VALUE CHAINS Fresh produce

Inficold
NAME Inficold
LAUNCHED 2015
COUNTRY India
FOCUS Cold storage
VALUE CHAINS Fresh produce, poultry, flowers, dairy

Telefónica Tech
NAME Smart Agro 4.0
LAUNCHED 2019–2021 (pilot)
FOCUS Irrigation
COUNTRIES Colombia, Peru, El Salvador
VALUE CHAINS Fresh produce, cotton, coffee

Note: All services included are commercially available unless noted by the use of the word pilot and/or an end-date in the "Launched" field.
Source: D4Ag providers

Benefits of smart crop management: higher yields

D4Ag providers are reporting significant productivity gains from the use of their solutions, especially in terms of higher yields. This is particularly true of high-margin fruits, vegetables, mushrooms and spices (see Figure 12).

Figure 12

Average yield increases following the implementation of various smart irrigation solutions, by crop[38]
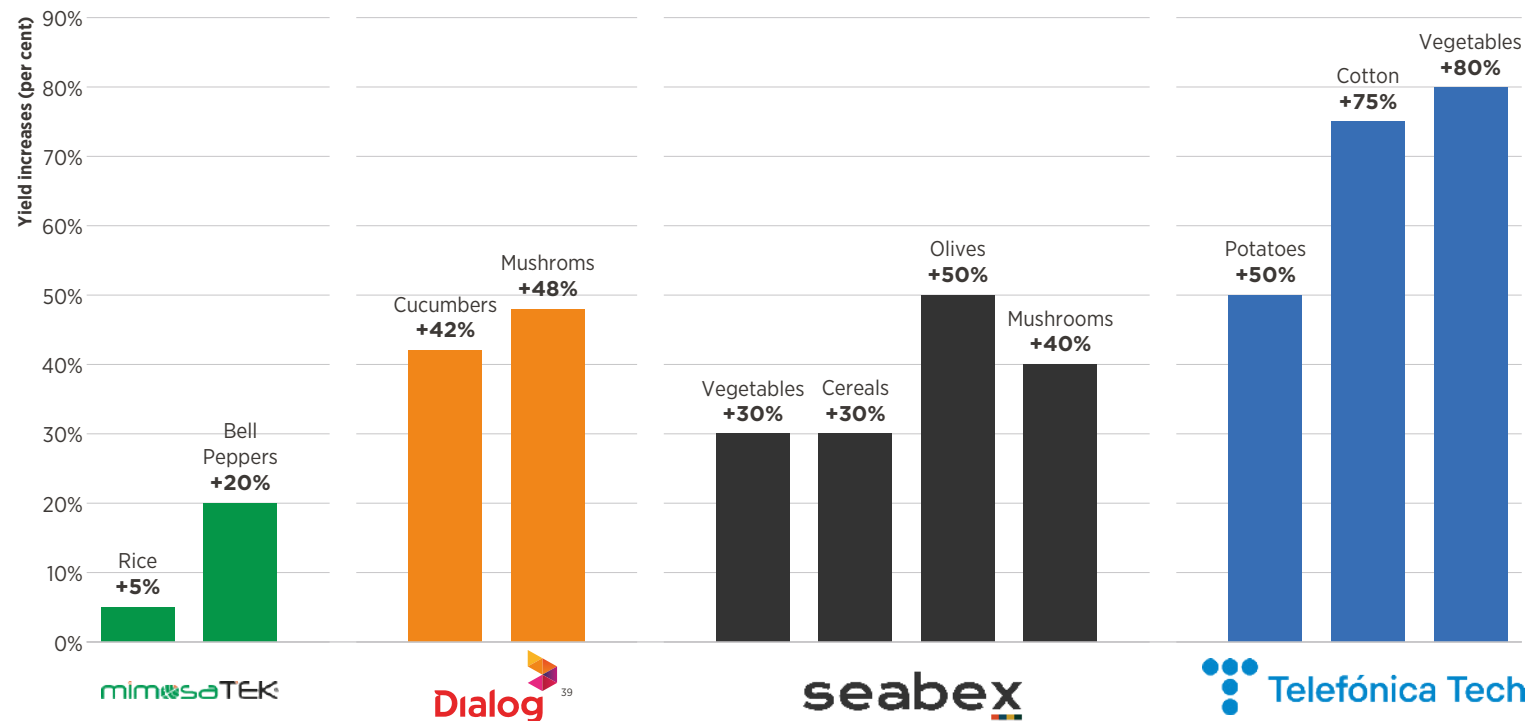
Source: MimosaTEK, Dialog, Seabex, Telefónica

38 Data presented in this chart is reported by the D4Ag providers themselves and is indicative and not directly comparable across providers. Data collected by Dialog and Telefónica comes from small-scale controlled pilots. Data collected by MimosaTEK and Seabex comes from wider-scale commercial deployments.
39 GSMA. (2020). *Local partnerships to drive affordable smart farming with Dialog Sri Lanka.*
    Available at: https://www.gsma.com/mobilefordevelopment/uncategorized/local-partnerships-to-drive-smart-farming-with-dialog-sri-lanka/.

Benefits of smart crop management: cost savings

In addition to the potential benefits of improved yields, smart crop management solutions can also lower costs (see Figure 13). Particularly compelling for farmers are solutions that help lower the cost of fertilisers and pesticides and reduce the need to hire labour to monitor fields for frequent irrigation or fertiliser application. We are aware of the potentially negative impact that smart farming solutions can have on rural employment if sensors translate into job losses in the field. Our hypothesis, which we will need to monitor over time, is that productivity gains will lead to more, rather than less, employment opportunities in rural areas.

Figure 13

Areas of potential cost savings for smallholders implementing smart crop management solutions

Lower pesticide and fertiliser use	Lower labour costs/ time savings	Lower energy costs
More precise soil readings translate into more targeted application of fertilisers and pesticides.	Automation of irrigation and fertiliser application reduces the need to hire extra labour.	Solar-powered solutions, like solar-powered water pumps or cold storage solutions, can help smallholders save energy costs.
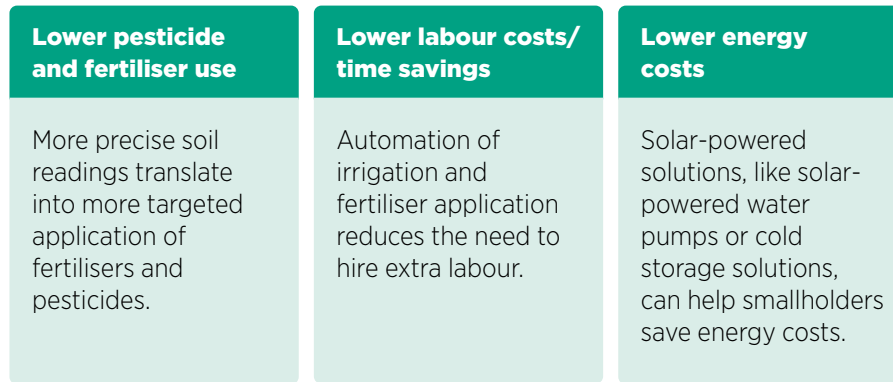
Source: : Digital Agri Hub

Figure 14

Cost savings observed by D4Ag providers implementing smart crop management solutions in South Asia

iFarmer
16.8% [40]
Reduced input costs

Dialog
30–40% [41]
Reduced labour costs

ANANKE
25% [42]
Increased efficiency in withering process
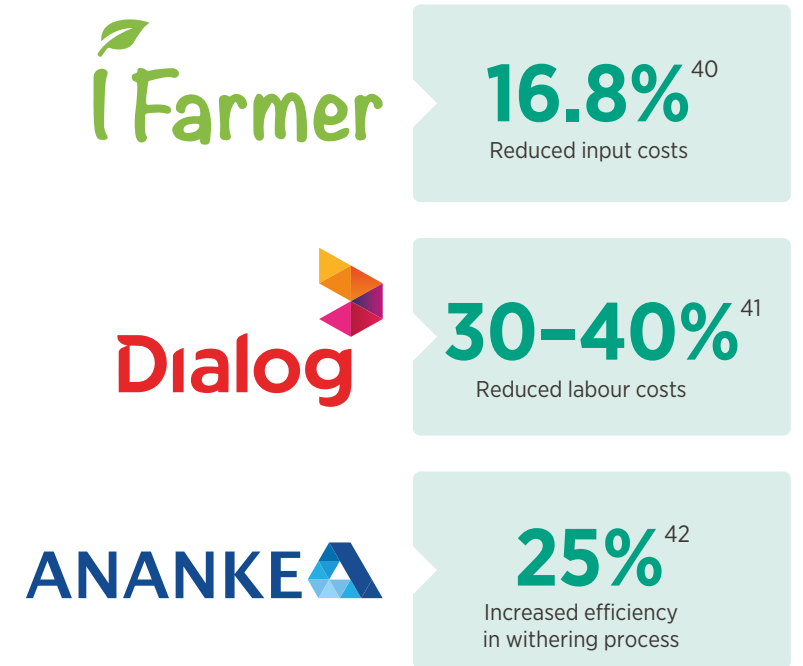
Source: D4Ag providers

40 iFarmer's own estimate provided during interview (September 2021).
41 Dialog's own estimates as reported in GSMA. (2020). *Local partnerships to drive affordable smart farming with Dialog Sri Lanka.* Available at: www.gsma.com/mobilefordevelopment/uncategorized/local-partnerships-to-drive-smart-farming-with-dialog-sri-lanka/.

42 ANANKE IoT's own estimates as reported in Effective Solutions, *Improving the Quality of Ceylon Tea with ANANKE IoTea.* Available at: https://effectivesolutions.xyz/improving-the-quality-of-ceylon-tea-with-ananke-iotea/.

Benefits of smart crop management: conservation of scarce resources

Because water is available free of cost to many farmers in LMICs, water conservation has not emerged as a compelling reason for smallholders to adopt smart crop management solutions (although it remains compelling for governments, NGOs and agribusinesses that sometimes subsidise these solutions. See Figure 53 on page 81 for examples of subsidies). Tunisia's Seabex has helped their customers reduce water consumption by 30 to 50 per cent while boosting crop production 10 to 50 per cent.[43] Telefónica has observed savings of 18 to 25 per cent from the use of their smart farming solution (see Figure 15).

Figure 15

Reduced water use following implementation of the Telefónica/FAO smart crop management solution in Peru, 2021[44]

Legend: Traditional method ■ Smart farming method
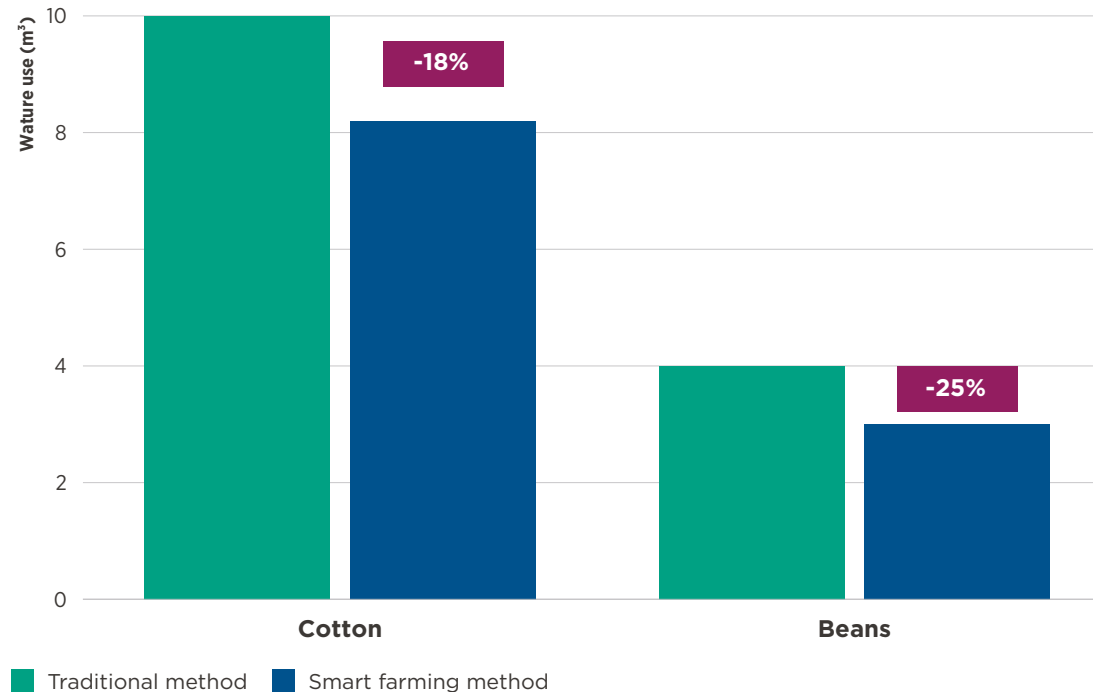
Source: Telefónica

43 Seabex' own estimate provided during interview (October 2021).

44 Telefónica. (2021). *Smart Agro Perú: Una Alianza De Telefónica, FAO y Brasil, Contribuyendo para +Algodón.*
Available at: https://iot.telefonica.com/es/whats-new/news/smart-agro-per%C3%BA-una-alianza-de-telef%C3%B3nica-fao-y-brasil-contribuyendo-para-plusalgod%C3%B3n/.

SunCulture's solar-powered irrigation system helps smallholders increase productivity and incomes

CASE STUDY

SunCulture is a Kenya-based D4Ag company that provides solar-powered pumps and irrigation systems to smallholder farmers in Kenya, Uganda, Ethiopia, Côte d'Ivoire, Togo, Senegal and Zambia. SunCulture aims to improve farmer livelihoods by boosting productivity while reducing the time and cost of production. SunCulture claims that their systems can improve productivity by up to 300 per cent while reducing water usage by up to 80 per cent.[45] In September 2020, impact measurement firm 60_decibels conducted a survey of 251 SunCulture customers to assess the impact of their solar-powered water pumps on farmer incomes and quality of life (see Figure 16). The average survey respondent had been using a SunCulture solar-powered irrigation system for at least 12 months and cultivated an average of 1.5 acres of land.[46]

Figure 16

The impact of using SunCulture's solar-powered water pump on smallholder farmers'…

…farm income

Very much increased/improved	Slightly increased/improved
42%	38%

…production

Very much increased/improved	Slightly increased/improved
62%	25%

…quality of life

Very much increased/improved	Slightly increased/improved
80%	15%

■ Very much increased/improved   ■ Slightly increased/improved

Source: SunCulture, World Bank, 60_decibels

> I spent six to eight hours per day collecting water manually with very little yield. [Since starting to use the SunCulture RainMaker system] my income has increased from $107 to $357 (KES 12,000 to 40,000) per month and I can also harvest during the dry season.
>
> **Kitui, SunCulture farmer [47]**

45 SunCulture. (2021). Available at: https://sunculture.com/index.php/about-us/.
46 SunCulture. (2020). Case Studies and Impact. Available at: https://olc.worldbank.org/system/files/Presentation%20-%20Case%20studies%20%26%20Impact%20by%20Benson%20Gathungu%20from%20SunCulture.pdf.
47 Ibid.

Smart livestock management solutions

1/2

Over the past five to eight years, a number of digital solutions have emerged in LMICs to help smallholder livestock and aquaculture farmers optimise their operations and improve productivity and incomes (see Figure 17). Smart livestock management solutions help farmers with containment and theft prevention, health and reproduction, identification of predatory threats and long-term management. Through the use of sensors, livestock farmers can better predict animal behaviour. Disease in livestock can be identified almost immediately rather than the 48 hours it typically takes.

Sensors can also identify when cows are going into oestrus (a phase that typically happens at night and is therefore missed by farmers) to ensure that insemination takes place in a timely manner. Although mostly used with cattle, smart livestock solutions can also be suitable for containing and monitoring goats, sheep and other types of herds. Smart poultry solutions that use IoT sensors to manage the health of poultry by sending alerts when anomalies are detected in poultry enclosures, are typically applied on large-scale farms, although a couple of small-scale applications have been identified in LMICs.

Figure 17

Example of a smart livestock application[48]

Chipsafer device

Transmission through LoRaWAN

Recharges through a solar panel

GPS-enabled

Each device is mounted to a cow using a collar

Device enables remote monitoring and fencing of cattle

Source: Chipsafer

48 Chipsafer. (2022). Available at: https://www.chipsafer.com/our-product.

Smart livestock management solutions

Smart aquaculture management solutions are used to optimise the use of feed, monitor seafood health and automate the feeding process (see Figure 18).[49]

Figure 18

Example of a smart aquaculture application[50]

eFishery eFeeder implementation in a catfish farm in Cirebon

eFishery coordinator assisting catfish farmer

Source: eFishery

49 Aquaculture farmers in LMICs that occupy relatively small areas are still considered smallholder farmers. Unlike the traditional smallholder or subsistence farmer that is the target of many of the smart farming solutions profiled in this report, aquaculture farmers tend to use more intensive production systems, translating into higher average income for aquaculture farmers.

50 Photo images provided to Digital Agri Hub by eFishery.

Smart livestock management solution deployments in LMICs

Livestock management solutions have been impactful in the context of large-scale agriculture in developed markets. However, the implementation of these solutions in the context of smallholder farming in LMICs has proven more challenging, as evidenced by the fact that several early initiatives have since ceased to operate and some pilots failed to get off the ground. Livestock management solutions are present across all regions (see Figure 19).
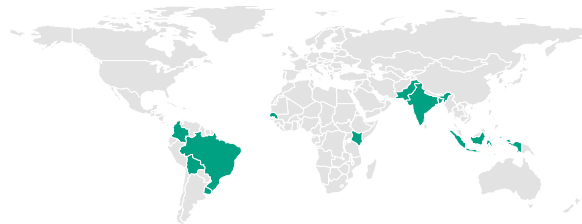
Figure 19

Selected smart livestock management solutions, 2021

CELOTOR

NAME	LAUNCHED
Celotor	2012
COUNTRIES	**FOCUS**
Colombia, Bolivia	Reproduction management
VALUE CHAINS	
Livestock and dairy	

ASC

NAME	LAUNCHED
Africa Smart Citizens	n/a
COUNTRY	**FOCUS**
Senegal	Livestock theft prevention
VALUE CHAINS	
Livestock	

stellapps

NAME	LAUNCHED
mooOn (Stellaps)	2011
COUNTRY	**FOCUS**
India	Livestock health and milk production
VALUE CHAINS	
Dairy	

MISFIT TECHNOLOGIES

NAME	LAUNCHED
Cowdy	(Pilot)
COUNTRY	**FOCUS**
Bangladesh	Reproduction management
VALUE CHAINS	
Livestock and dairy	

chipsafer

NAME	LAUNCHED
Chipsafer	2012
COUNTRIES	**FOCUS**
Uruguay, Brazil[51]	Livestock theft prevention
VALUE CHAINS	
Livestock	

Myfugo

NAME	LAUNCHED
Myfugo	2018
COUNTRY	**FOCUS**
Kenya	Livestock health and milk production
VALUE CHAINS	
Dairy	

COWLAR

NAME	LAUNCHED
Cowlar	2015
COUNTRY	**FOCUS**
Pakistan	Livestock health and milk production
VALUE CHAINS	
Dairy	

SMARTernak

NAME	LAUNCHED
SMARTernak	2018
COUNTRY	**FOCUS**
Indonesia	Livestock monitoring
VALUE CHAINS	
Dairy	

Source: D4Ag providers

51   Chipsafer is incorporated in Singapore and manufactures its smart collars in the country. It sells primarily to farms and farmers in South America.

Benefits of smart livestock solutions: higher yields and improved animal health

For livestock farmers, loss from theft has become a significant problem, particularly in Africa where cattle rustling has led to millions of dollars in losses and thousands of lives lost due to the associated violence.[52] Poor health and a missed ovulation cycle can also cost livestock farmers hundreds if not thousands of dollars each year. iFarmer in Bangladesh estimates that each missed ovulation cycle can cost a farmer $150 (13,000 Taka).[53] iFarmer also stated that without using sensor technology, it can take a farmer up to 48 hours to detect an illness in an animal. The farmer can therefore incur high veterinary fees and lose income from the sale of a sick animal. Stellapps, a digital procurement and livestock management solution provider in India, has reported major benefits from the use of their cattle sensors (see Figure 20).

Figure 20

Stellapps' internal reporting on the benefits of using mooON smart wearables and the smartAMCU procurement platform[54]

20% increase in milk yield

50% reduction in cattle health expenses

10% reduction in administrative expenses

1 month reduction in intercalving period
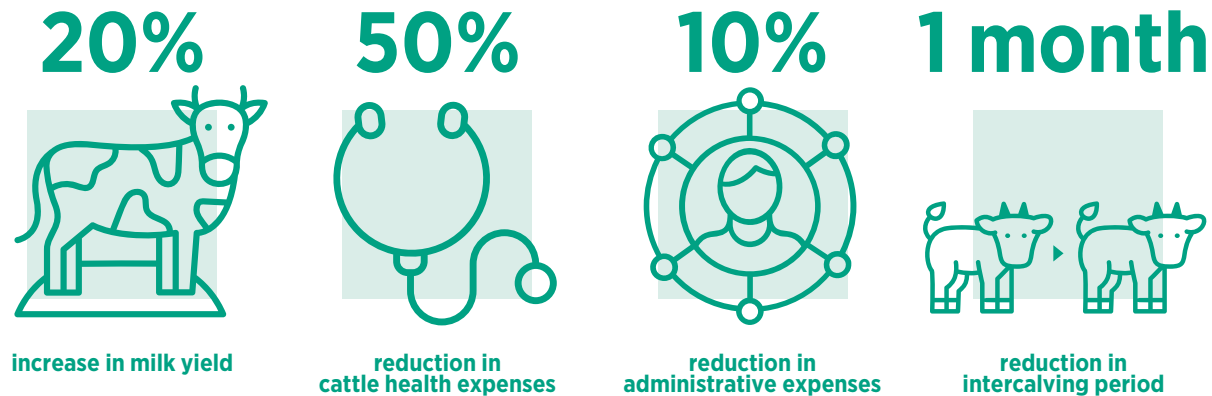
Source: Stellapps

I've been using Cowlar's system for a year. Milk yield is 15 per cent higher than last year and we have not missed a single heat [this year].

Cowlar farmer (with 10 cows)[55]

52   ENACT Africa. (2020). *Rise of East Africa's cattle cartels*.
     Available at: https://enactafrica.org/press/press-releases/rise-of-east-africas-cattle-cartels.
53   iFarmer interview (September 2020).

54 Stellaps' own estimates as reported on its website. (2021). Available at: www.stellapps.com/mooon/.
55 As reported by Cowlar on its website. Available at: www.cowlar.com/

Smart aquaculture management solution deployments in LMICs

D4Ag providers offering smart aquaculture solutions are newer to the market, with most solutions identified having been introduced between 2017 and 2020 (see Figure 21). Most aquaculture management solutions are present in Southeast Asia, where the aquaculture industry is growing at double digit rates.[56]

Figure 21

Selected smart livestock management solutions, 2021

Eruvaka

NAME	**LAUNCHED**
Eruvaka Technologies	2012
COUNTRIES	**VALUE CHAINS**
India, Ecuador, Honduras, Mexico, Nicaragua, Panama, Peru, Vietnam	Fish and shrimp
	FOCUS
	Fish health and production

AQUArech

NAME	**LAUNCHED**
Aquarech	2019
COUNTRY	**FOCUS**
Kenya	Fish health and production
VALUE CHAINS	
Fish	

FisTx

NAME	**LAUNCHED**
FisTx	2020
COUNTRY	**FOCUS**
Indonesia	Fish health and production
VALUE CHAINS	
Fish	

eFishery

NAME	**LAUNCHED**
eFishery	2020
COUNTRY	**VALUE CHAINS**
Indonesia, Thailand, Vietnam, Bangladesh	Fish and shrimp
	FOCUS
	End-to-end aquaculture management solution

piscis

NAME	**LAUNCHED**
Piscis/ABACO	2021 (pilot)
COUNTRY	**FOCUS**
Peru	Fish health and production
VALUE CHAINS	
Trout	

skylo

NAME	**LAUNCHED**
Skylo	2021/22 (pilot)
COUNTRY	**FOCUS**
India	Fish health and production
VALUE CHAINS	
Fish	

AquaEasy

NAME	**LAUNCHED**
AquaEasy (Bosch)	2020
COUNTRY	**FOCUS**
Vietnam	Fish health and production
VALUE CHAINS	
Fish	

JALA

NAME	**LAUNCHED**
JALA	2017
COUNTRIES	**VALUE CHAINS**
Indonesia, Malaysia, Vietnam, Thailand, Ecuador	Shrimp
	FOCUS
	Fish health and production
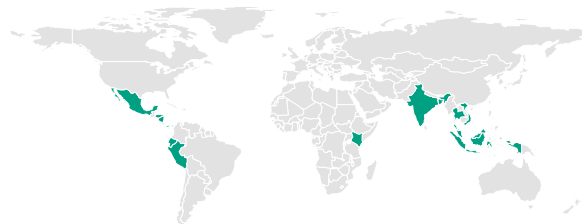
Source: D4Ag providers

56 FAO. (2020). *The State of World Fisheries and Aquaculture*. Available at: www.fao.org/3/ca9229en/ca9229en.pdf.

Benefits of smart aquaculture: optimised operations and higher yields

For aquaculture farmers, the cost of feed can represent up to 70 to 80 per cent of total operating costs.[57] In addition, overfeeding can lead to water contamination/pollution and fish mortality. Solutions that help to lower the feed conversion ratio (FCR)[58] not only save farmers money by lowering operating expenses, but they can also translate into better quality fish and higher yields (see Figure 22). eFishery's internal data suggests that their clients, 95 per cent of whom are smallholder farmers, saw their average income increase 93 per cent as a result of using eFishery's automatic feeders and end-to-end aquaculture management solution.[59] One of the main benefits has been the reduction in harvesting time, from three to two months.[60] Thanks to these reported productivity gains, eFishery has seen dramatic growth in their user base (see case study, page 69).

Figure 22

Declines in FCR as a result of implementing smart farming solutions[61]

Source: Eruvaka Technologies, eFishery, JALA

Figure 23

Reported yield increase from the use of smart aquaculture management solutions in Vietnam[62]

2,000 kg juvenile fish placed in pond

Conventional aquaculture management
30,000 kg fish produced without the use of sensors. Average fish deaths of ~40%.
$45,000 Income per cycle

Smart aquaculture management
38,000 kg fish produced with the use of sensors. Fish deaths of ~20–24%.
$57,000 Income per cycle

Source: Libelium

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57 Global Aquaculture Alliance. (2014). May/June issue of the Global Aquaculture Advocate. Available at: https://aquafishcrsp.oregonstate.edu/sites/aquafishcrsp.oregonstate.edu/files/priceegna2014strategiesforreducingfeedcosts_gaa.pdf.

58 According to the FAO, "Feed conversion ratio (FCR), in its simplest form a comparison of the amount of feed used per unit weight gain of the species being grown, offers a measure of aquaculture production efficiency. It also indicates environmental performance, since it provides an indication of the undesirable outputs and lost nutrients to the environment, with potential consequences such as accelerated eutrophication, loss of biodiversity and other ecosystem services." Source: FAO. (2017). Improving Feed Conversion Ratio and Its Impact on Reducing Greenhouse Gas Emissions in Aquaculture. Available at: www.fao.org/documents/card/en/c/83b8df36-bfaf-4d63-ac0a-0982bb6ebbf7/.

59 eFishery's own estimates as provided during interview (October 2021).

60 Ibid.

61 eFishery's own estimates as provided during interview (October 2021); JALA's own estimates as provided during interview (November 2021); Eruvaka Technologies' own estimates as reported on its website: https://eruvaka.com/#why.

62 Libelium's own estimates. (2016). Fish farm monitoring in Vietnam by controlling water quality in ponds and tanks, available at: https://www.libelium.com/libeliumworld/success-stories/fish-farm-monitoring-in-vietnam-by-controlling-water-quality-in-ponds-and-tanks/.

MyFugo leverages IoT to help smallholder farmers access financing and increase milk production and incomes

CASE STUDY

Kenya's MyFugo was founded in 2018 with the aim of helping smallholder livestock farmers earning less than $1.60 per day improve their livelihoods through access to financing, agronomic advice and solutions that can help them improve the performance of their herds and, therefore, their ability to repay their loans.
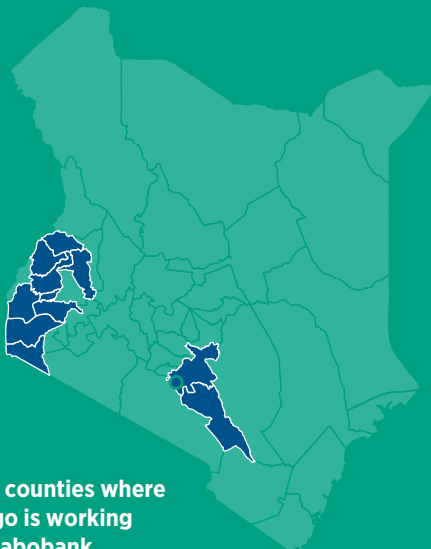
Kenya counties where MyFugo is working with Rabobank

Challenges identified

1 Drought negatively impacts the availability, quality and price of livestock feed, translating into less healthy animals.

2 Less healthy animals produce less milk.

3 Farmers lack access to finance that can enable them to expand their herd and acquire higher-producing breeds.

4 Farmers lack the knowledge and tools needed to maximise production.

Actions taken[63]

In 2020, MyFugo teamed with Rabobank to provide financing to 1,800 farmers from 40 cooperatives. With Rabobank's backing, MyFugo:

1 Extended loans to farmers to acquire better breeds.

2 Provided microfinancing to farmers to acquire feed and veterinary care, including vaccinations and insemination.

3 Provided IoT-equipped smart collars to smallholders to monitor the health of their cows.

4 Provided training and advisory.

Source: MyFugo, Rabobank

Results

Initial results were promising, so Rabobank extended their financial support into 2021. MyFugo now has a waiting list of 13,000 farmers. Among the results reported in 2020:

5× income

4× milk production

10× fewer cow deaths

65% women

63 Rabobank. (2021). *A better life through profitable cattle*. Available at: www.rabobank.nl/en/about-us/rabofoundation/project/011143016/a-better-life-through-profitable-cattle.

Mechanisation access services

Mechanisation access services enable farmers to access agricultural equipment, such as tractors, drones, threshers, tilling machines and other farm equipment, via digital booking systems. The equipment is usually fitted with IoT-enabled tracking devices to allow owners of the equipment to track the location and performance of their assets. A key advantage of the model is that it enables a single piece of machinery to serve hundreds of farmers who do not typically have access to such equipment. Hello Tractor estimates that a single tractor can serve more than 500 farmers in any given year.[64]

Mechanisation access services also help farmers save time and lower their land preparation costs.

Mechanisation access services are the most recently introduced smart farming solutions analysed in this study (see Figure 24). The earliest, and perhaps most well-known, examples of the mechanisation access services model are Africa's Hello Tractor and India's EM3 Agri Services, both of which initiated operations in 2014. Since then, many companies have entered the space, including TROTRO Tractor, Vaya Tractor and GetzTrac, among others.

Figure 24

Timeline for the introduction of mechanisation access services in LMICs
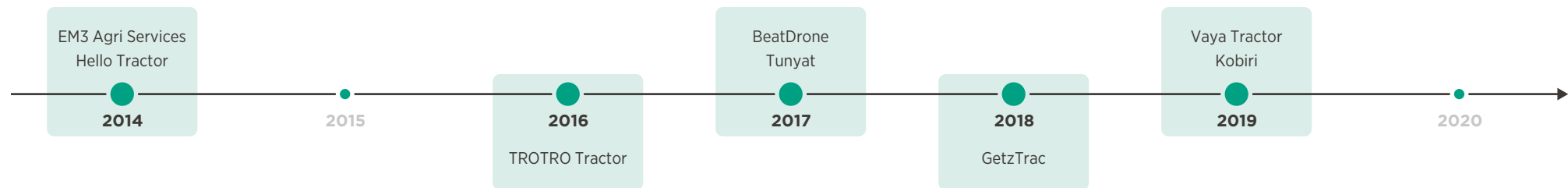
Source: D4Ag providers

64 Hello Tractor interview (May 2022). The New Stack. (2019). *Hello Tractor: An App-Driven Ecosystem for Tractor-Sharing.* Available at: https://thenewstack.io/hello-tractor-an-app-driven-ecosystem-for-tractor-sharing/.

Mechanisation access service deployments in LMICs

Most of the shared asset solutions identified by the Digital Agri Hub team can be found in Africa, South Asia and Southeast Asia (see Figure 25).

Figure 25

Selected mechanisation access services, 2021

kobiri

NAME
Kobiri

COUNTRY
Guinea Conakry

LAUNCHED
2019

hello tractor

NAME
Hello Tractor

COUNTRIES
Africa × 14
Asia × 2
Americas × 2

LAUNCHED
2014

BEAT DRONE

NAME
BeatDrone

COUNTRY
Nigeria

LAUNCHED
2017

GetzTrac

NAME
Getztrac

COUNTRY
Thailand

LAUNCHED
2018

EM3 AgriServices

NAME
Samadhan

COUNTRY
India

LAUNCHED
2014

TROTRO Tractor Limited

NAME
TROTRO Tractor

COUNTRIES
Ghana, Togo,
Benin, Nigeria

LAUNCHED
2017

VAYA

NAME
Vaya Tractor[65]

COUNTRIES
Zimbabwe, Togo

LAUNCHED
2019

TUN YAT

NAME
Tun Yat

COUNTRIES
Myanmar

LAUNCHED
2017

Note: All services included are commercially available unless noted by the use of the word pilot and/or an end-date in the "Launched" field.
Source: D4Ag providers

65 Vaya Tractor leverages TROTRO Tractor's platform in Zimbabwe. The two companies work jointly in Benin.

The benefits of mechanisation

Figure 26

Benefits of farm mechanisation[66]

More efficient use of labour	The menial work associated with on-farm and off-farm operations results in low efficiency and poor yield performance. Women experience an increased work burden when men migrate to urban areas for employment. Mechanisation increases the efficiency of labour.
Timeliness of farming operations	Mechanisation allows farm and non-farm operations to be executed precisely within a short period. This timeliness is crucial for planting, harvesting and threshing since delays can have a severe impact on final yields.
Efficiency in labour, operations and agricultural inputs	The use of power sources increases the efficiency of on- and off-farm operations, saving time that farmers could spend working more land. Similarly, the use of machinery and equipment can increase the efficiency of using agricultural inputs such as seeds and fertilisers.
Surplus production	The surplus that comes from increased mechanisation allows small subsistence farmers to develop into market-oriented commercial farmers, selling their extra production at a profitable price.

Source: FAO

Figure 27

Impact of mechanisation on production[67]

Human power
The labour of 1 human can feed…
3 people
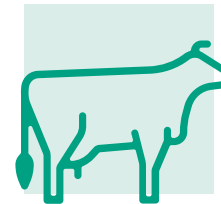
Animal power
The labour of 1 human can feed…
6 people

Machine power
The labour of 1 human can feed…
50 people

Source: FAO

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66 FAO elearning Academy. (2021). *Small-scale agricultural mechanization hire services as a business enterprise*. Available at: https://elearning.fao.org/course/view.php?id=711.
67 Ibid.

Benefits of mechanisation access services: increased productivity and yields

Mechanisation access service providers have reported significant productivity gains as a result of the use of their platforms. A reduction in time it takes to complete tasks is translating into significant cost savings for many smallholder farmers in LMICs (see Figure 28).

Figure 28

The impact of mechanisation access services on farmer productivity

SAYeTECH

15 days to 2 days

Estimated reduction in threshing time of one acre of land using a SAYeTECH multi-cropped threshing machine equipped with a remote monitoring device.[68]

hello tractor

40%

Estimated reduction in land preparation costs associated with the use of a Hello Tractor tractor equipped with a remote monitoring device.[69]

Source: SAYeTECH and Hello Tractor

> I am happy that I only paid $100 to Hello Tractor and they finished the job in a day. If the work was done by hand, it would have taken several days to complete.
>
> **Aliyu Ayuba, Nigerian farmer with 2 hectares[70]**

68 SAYeTECH's own estimates as reported at: https://sayetech.io/.
69 Hello Tractor's own estimates as reported in OPEC Fund. (2019). Big help for Africa's smallholder farmers. Available at: https://opecfund.org/news/big-help-for-africa-s-smallholder-farmers.

70 Agrilinks. (2021). *Digital Partnerships Help Transform Agripreneurship in Africa*. Available at: https://www.agrilinks.org/post/digital-partnerships-help-transform-agripreneurship-Africa.

TROTRO Tractor has helped farmers increase yields by 50 to 66 per cent

CASE STUDY

TROTRO Tractor is a Ghana-based D4Ag provider that has adopted the shared-tractor model in Ghana and several other markets, including Zimbabwe, Benin, Togo and Nigeria, in partnership with Econet Zimbabwe's Vaya Tractor and Tata Tractors. The company was founded in 2016 with the goal of making mechanisation assets available to the more than 60 per cent of farmers in Ghana who rely primarily on small tools for land preparation and harvesting.[71] As of year-end 2021, TROTRO Tractor had more than 600 tractors on their network and served more than 35,000 farmers in Ghana. TROTRO Tractor takes a 10 per cent commission on all bookings made via their app.[72]

Figure 29

TROTRO Tractor service[73]

B2B

SMALLHOLDER FARMER

TROTRO Tractor will enable high net-worth individuals to own Decentralised Mechanisation Centres leveraging TROTRO Tractor's technology.

1 Farmer requests services via USSD (Short Code)
2 TROTRO Tractor automatically matches to the nearest hub
3 Service is delivered by an operator within 72 hours
4 Maintenance/repair of tractor and machinery

Figure 30

TROTRO Tractor pricing, Ghana[74]

Farmers

PAY	PAY
$20 per acre	**$26 per acre**
Northern Ghana	Southern Ghana

Tractor owners

EARN	PAY
90% of farmer payment	**$266 per GPS device installed on tractor**

Source: TROTRO Tractor

71 TROTRO Tractor presentation (2021).
72 TROTRO Tractor interview (September 2021).
73 TROTRO Tractor and ADA Microfinance. (2019). Agritech innovations transforming the landscape of rural finance and livelihoods. Available at: www.ada-microfinance.org/sites/default/files/2020-12/agritech-innovations.pdf.
74 TROTRO Tractor presentation (2021).

Trends in smart farming solutions

TREND #1

Smart farming solutions have had a strong focus on high-end, capital-intensive value chains like horticulture, aquaculture and livestock, in contrast to other digital agriculture solutions that have a stronger focus on cash crops.

This is especially the case with smart crop management solutions. Although we identified some smart farming solutions being used for cash crops such as cotton (Telefónica Smart Agro 4.0), coffee (Telefónica Smart Agro 4.0 and MimosaTEK) and grains (MimosaTEK), the vast majority of smart crop management solutions are deployed in the cultivation of fruits, vegetables, flowers and spices. Where smart crop management solutions are used for cash crops like coffee, the service is often subsidised by an agribusiness or NGO. Farmers growing cucumbers, bell peppers, melons, mushrooms, paprika and others, are among those who have enjoyed the biggest productivity and income gains as a result of using smart crop management services.

Figure 31

Factors that make a value chain suitable for smart crop management solutions

1 Quick cultivation cycle (measured in months not years)

2 Frequent irrigation (typically many times per day)

3 Can be grown on a flat field or enclosure

4 Perishable

5 Higher-margin crops where the price is not set internationally

Trends in smart farming solutions

TREND #2

Smart farming services require a robust technical background and strong digital services know-how.

Unlike other digital agriculture solutions that rely primarily on platforms, smart farming solutions often involve the use of high-tech equipment, including sensors, drones, greenhouses, irrigation systems and packhouses, among others. Given the technical expertise required to run these services, agribusinesses, NGOs, cooperatives or MNOs – groups leading many digital advisory, procurement or agri digital financial services products – have been less active in the smart farming space, deferring in many cases to technology companies, which have taken the lead. The Digital Agri Hub team identified only a handful of MNO-led initiatives aimed at smallholder farmers, including Dialog's Saru, Telefónica's Smart Agro 4.0 and Econet's Vaya Tractor. Other MNOs have become involved in smart farming solutions, including Orange (Seabex, Africa Smart Citizens), Liquid Intelligent Networks (Takuwa Farms), Viettel and MTN. However, they are either taking a supporting or advisory role or focusing on services aimed at larger farms, such as Vodacom's MyFarmWeb. Bangladesh's Grameenphone had been testing smart livestock and crop management solutions, but has since deferred to Misfit's iFarmer to roll out these services. We have identified a few solutions being piloted by cooperatives with the support of technology companies (e.g. Piscifactoria de los Andes in Peru working with Umitron and FISCHOPFED in India working with Skylo). One of the tools identified, Vietnam's Aquaeasy, is backed by Germany's Bosch, a multi-billion dollar technology company.

D4Ag PROVIDER-LED

mimosaTEK · eFishery · GetzTroc · GramworkX · AQUARECH · JALA · Synnefa · seabex · gricd · TECHSHELTA · CHIPSAFER · Eruvaka · Futurepump · SMARTernak · hello tractor · COWLAR · !nspiraFarms · iFarmer · Fasal · TUNYAT · SunCulture · MYFUGO · EM3 Agri Services

MNO-LED

Telefónica Tech · Dialog · TROTRO Tractor Limited

DONOR/INVESTOR-LED

HEIFER INTERNATIONAL

COOPERATIVE-LED

piscis

Trends in smart farming solutions

TREND #3

The mechanisation access and aquaculture management service sub-use cases have seen the highest user numbers, but only aquaculture management providers have been able to translate that into investor funding.

To date, mechanisation access service providers have reported the highest user figures. Hello Tractor reports that more than 500,000 farmers have accessed mechanisation equipment via their platform since 2014. TROTRO Tractor has worked with roughly 35,000 farmers in Ghana while Vaya Tractor has worked with more than 80,000 farmers in Zimbabwe, Benin and Togo. Despite these numbers, mechanisation access providers have struggled to secure funding to scale their operations. Providers have struggled to move from one-off use of their services to ongoing use. Companies have also struggled to align supply and demand as tractors are often not available when and where they are needed. This has caused several providers to adjust their operational model. TROTRO Tractor, for example, is looking to team with distributors in various districts that would own the agricultural equipment and lease it using the TROTRO Tractor app.

Although total aquaculture management provider user numbers are not as high as those reported by mechanisation access services, they have been more successful at securing funding. Indonesia's eFishery, for example, recently closed a Series C round of financing totalling $90 million.[75] Eruvaka Technologies closed a Series B round of financing in 2018 totalling $5 million.[76] Several of the aquaculture solution companies identified for this study have attracted 10,000 or more users within the last two years – users that pay monthly usage fees, not one-off fees. Many have also succeeded in selling beyond their domestic markets. For example, up to 90 per cent of India-based Eruvaka Technologies' sales are to aquaculture farmers in either Latin America or Southeast Asia.[77] JALA and eFishery have each been expanding throughout Southeast Asia and South Asia in recent years, taking advantage of the growth in the aquaculture market in these countries. Livestock and smart crop management solutions, by contrast, have struggled to scale beyond a few hundred or a few thousand users in LMICs.

75 AgFunder News. (2022). *Indonesia aquatech startup eFishery nets $90m in Sequoia, Softbank-led series C.* Available at: https://agfundernews.com/efishery-nets-90m-for-series-c-round-aquaculture.

76 Forbes India. (2021). *Eruvaka Technologies: Making high-risk, high-reward aquaculture farming predictable.* Available at: www.forbesindia.com/article/startups/eruvaka-technologies-making-highrisk-highreward-aquaculture-farming-predictable/68541/1.

77 Ibid.

Trends in smart farming solutions

TREND #4

D4Ag providers are refining their marketing pitch to focus on solutions that solve specific challenges faced by smallholders.

Although many of the D4Ag providers we interviewed for this study initially marketed the sophistication of their technology (IoT sensors, big data, AI) in their efforts to capture new clients, most have since realised that smallholders do not necessarily respond to the same high-tech pitch that might be suitable in more developed markets. D4Ag providers have therefore shifted from selling sensors and data to selling solutions and fixes to everyday problems. Synnefa (formerly Illuminum Greenhouses) pitches their "dashboard" rather than their AI/IoT-powered greenhouses. Indonesia's JALA sells their data-driven farm management platform. Investors also seem to prefer a focus on solutions that address specific smallholder challenges and have a clearer return on investment (ROI). Many D4Ag providers interviewed for this study have found it difficult to raise capital from investors if they are perceived to be hardware providers. A shift in positioning has not only made it easier for solution providers to sign on new customers, but it has also aided their efforts to raise much-needed capital from investors and donors, as evidenced by eFishery's recent Series C round of funding.

> We had this great idea and thought our customers would want our products to be more technology-oriented. But now we are more focused on the farmers' needs. We're transforming the company to be more customer oriented.
>
> **CFO, MimosaTEK**[78]

> IoT and Artificial Intelligence don't speak to all farmers. We need to turn these technologies into simple, actionable information that you can put in a farmer's hand, placing farmers in the driver's seat to drive those changes.
>
> **CEO, Seabex**[79]

78   Securing Water for Food. (2018). SWFF Support Helps Create Marketing Mindset & Better Product. Available at: https://securingwaterforfood.org/innovator-news/swff-support-helps-create-marketing-mindset-better-product.
79   Seabex interview (October 2021).

Trends in smart farming solutions

TREND #5

Smart farming solutions are often bundled with agri e-commerce platforms that connect farmers to input suppliers, traders and buyers to maximise the benefit to farmers.

IoT-based smart farming solutions have proven effective at increasing yields, but unless farmers are able to find a market for their products, the yield improvements do not necessarily translate into higher incomes (or additional sales for D4Ag providers selling the IoT-based solutions). As a result, many D4Ag providers offering smart farming solutions have introduced marketplace platforms over the last few years to help their customers maximise their income potential (see Figure 32). Service bundling can also benefit farmers by generating economies of scale that lower the cost of services to farmers and by enhancing the value proposition.

Figure 32

Examples of marketplaces added to smart farming solutions and platforms

AquaRech Kenya	Manages an app-based platform that enables buyers to purchase fish directly from aquaculture traders. It also enables farmers to acquire high-quality inputs directly from input suppliers.[80]
JALA Indonesia	Added a marketplace during the COVID-19 pandemic to help shrimp farmers identify new buyers/markets for their shrimp.[81]
eFishery Indonesia	Launched eFishery Fresh, an online platform linking buyers and sellers of different types of fish.[82]
MimossaTEK Vietnam	Assessing the introduction of a marketplace for their smart irrigation and digital advisory services to help farmers find new buyers for their crops.[83]
AgriEdge Morocco	In addition to its AI-based digital advisory services, AgriEdge launched a digital marketplace called AgriSoo9 that maximises farmers and cooperatives crop sales and helps them find new buyers.[84]

Source: D4Ag providers

80 AquaRech interview (October 2021).
81 JALA interview (November 2021).
82 eFishery
83 MimosaTEK interview (September 2021).
84 CE3M. (n.d.). "AgriSoo9, une plateform de e-commerce dédiée exclusivement aux agriculteurs et cooperatives". Available at: https://ce3m.ma/index.php/fr/allcategories-fr-fr/17-actualites/150-agrisoo9-une-plateforme-de-e-commerce-dediee-exclusivement-aux-agriculteurs-et-cooperatives.

Trends in smart farming solutions

TREND #6

Smart farming solutions have struggled to make inroads with female farmers.

This is especially the case with smart livestock solutions since the livestock and aquaculture industries in many LMICs tend to be male-dominated.[85] Indonesia's aquaculture solution provider JALA, for example, estimates that only one to two per cent of their clients are female farmers,[86] although they have endeavoured to bring more women onboard through women-led training sessions and outreach. Uruguay's livestock theft prevention IoT solution company Chipsafer has also found that most of their clients are men, a reflection of the overall industry.[87] Given that many D4Ag providers are in the initial customer acquisition stage of development, few have made a significant effort to ensure gender balance in their product portfolio.

This is where investors and donors can play a role in helping D4Ag providers develop gender-intentional strategies. For example, investors can tie funding to initiatives that intentionally target women by understanding what women need and how best to reach them. Kenya's AquaRech, an aquaculture IoT solution has an "intentional focus" on reaching female farmers.[88] The company has received a $50,000 equity-free grant from Google's 2020 Black Founders Fund, which requires it to target both female farmers and young farmers in their outreach.[89]

85 While the livestock industry tends to be male-dominated in many LMICs, we recognise that women play a larger role in livestock in several key geographies, most notably the Middle East. See GSMA. (2022). *Reaching and Empowering Women wih Digital Solutions in the Agricultural Last Mile.* Available at: www.gsma.com/mobilefordevelopment/resources/reaching-and-empowering-women-with-digital-solutions-in-the-agricultural-last-mile/.

86 JALA interview (November 2021).

87 Chipsafer interview (November 2021).

88 AquaRech interview (October 2021).

89 Meventum. (2021). *50 African startups secure equity-free funding from Google.* Available at: https://meventum.com/funding-news/50-african-startups-secure-equity-free-funding-from-google/.

3 Sizing the smart farming opportunity in LMICs

Market sizing and opportunity assessment

IoT connectivity is the backbone of smart farming technology, powering a wide variety of digital agriculture solutions. When it comes to the deployment of IoT technologies, the agriculture vertical is at an earlier stage of development compared to more established verticals like manufacturing, transportation and utilities. Despite this later start, the smart farming market is seeing significant growth, particularly in more developed markets. Various estimates put the size of the global market at $12 billion to $15 billion in 2020.[90] Some estimates predict the total market value will be up to $35 billion by 2026.[91] Although much of this opportunity will be concentrated in developed markets, growth in LMICs will be robust over the 2021–2026 period as more services become available.

The size of the smart farming opportunity and impact on smallholders will vary significantly by country. To assess the potential for smart farming in any given country, the Digital Agri Hub team constructed a bottom-up model for each sub-use case. The model relies on statistics gathered from each country on the current availability of different assets, such as irrigation pumps and tractors, to arrive at a total addressable market for IoT connections in the agricultural vertical. The figures presented here are an optimistic view of what the total addressable market could be if the right conditions are put in place in each market.

Figure 33

Building blocks of the smart farming market sizing model

Smart crop management =	# of irrigation pumps	✖	% managed by smallholders	✖	% with IoT connections
	Cold storage units	✖	% managed by smallholders	✖	% with IoT connections
Smart livestock management =	# of dairy cows	✖	% managed by smallholders	✖	% with IoT connections
	# of aquaculture ponds	✖	% managed by smallholders	✖	% with IoT connections
Mechanisation access =	# of tractors	✖	% managed by smallholders	✖	% with IoT connections

Source: Digital Agri Hub

90 Facts and Factors. (2021). *Global Smart Agriculture Market*. Available at: www.globenewswire.com/en/news-release/2021/10/18/2315821/0/en/Smart-Agriculture-Market-Size-Globally-Estimated-to-Reach-USD-22-5-Bn-with-8-9-CAGR-by-2026-Facts-Factors.html.

91 BIS Research. (2021). *Global Smart Farming Market*. Available at: https://www.reportlinker.com/p06185899/Global-Smart-Farming-Market-A-Global-and-Regional-Analysis-Focus-on-Solution-Application-Adoption-Framework-and-Country-Wise-Analysis-Startup-Analysis-Patent-Analysis-Value-Chain-Analysis-and-Forecast.html.

Smart farming opportunity

Figure 34

Smart farming IoT connections, by country, 2020–2026
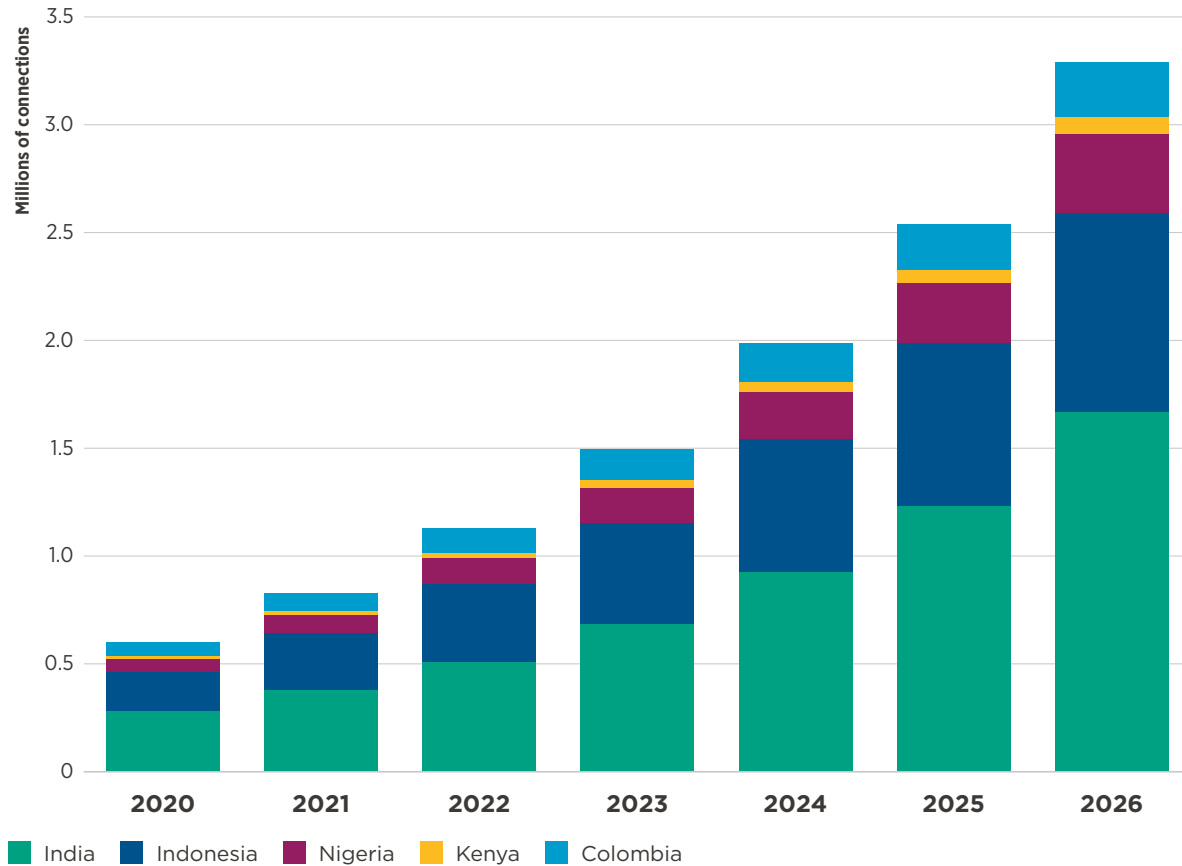
Source: Digital Agri Hub

Figure 35

Smart farming IoT connections, by sub-use case and country, 2026
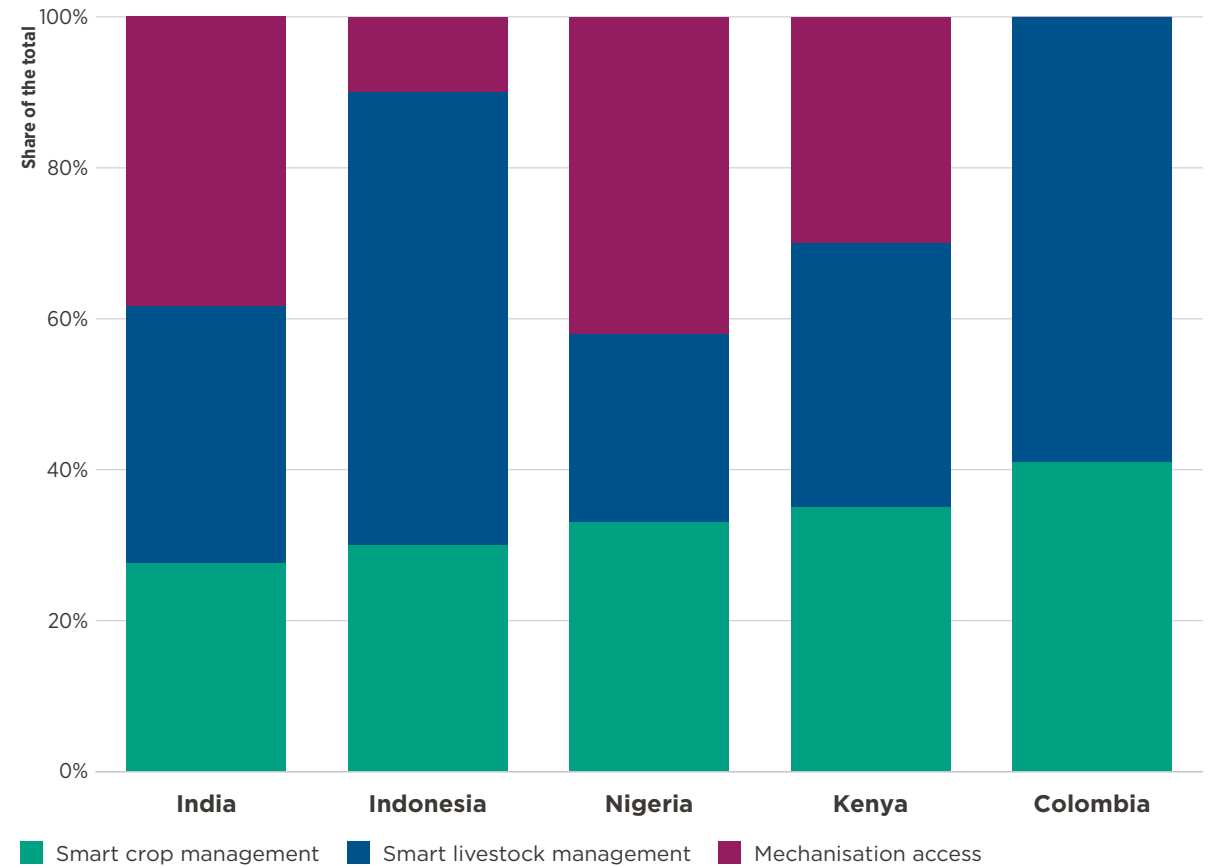
Source: Digital Agri Hub

4 Technologies that power smart farming solutions

Five-layer IoT network architecture

Smart farming solutions are made up of various building blocks that can be organised into three, four, five or seven layers, depending on the IoT architecture selected.[92] Figure 36 outlines a five-layer IoT network architecture that includes a perception, or device, layer that incorporates sensors, cameras and other devices; a network layer that includes gateways and connectivity networks; a processing layer responsible for aggregating the data; an application layer that analyses the data and prepares it for use across various platforms and devices; and the implementation layer, where the data interacts with end users in the form of recommendations, automated actions or services.

Figure 36

Five-layer IoT network architecture

Implementation layer

Application layer

Processing layer

Network layer

Perception layer
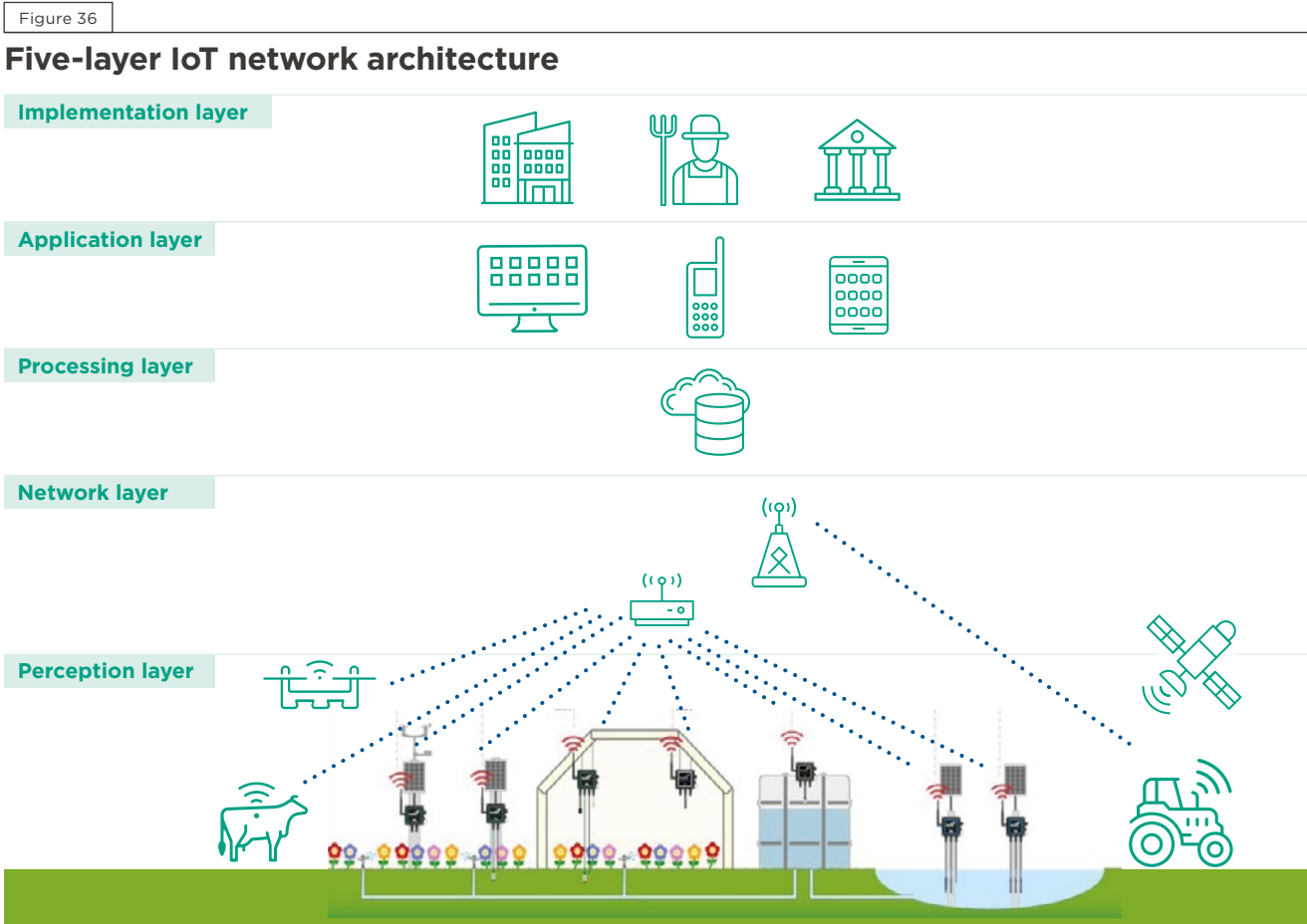
Source: Libelium, Science Direct

92 Science Direct. (2018). *The Internet of Things: Insights into the building blocks, component interactions, and architecture layers*. Available at: www.sciencedirect.com/science/article/pii/S1877050918309049.

The perception layer: data capture

In the context of agriculture, the perception layer – also known as the sensor or device layer – is made up of sensors or cameras that are attached to agricultural assets or monitor them from above. The purpose is to collect data that can be translated into insights, recommendations and/or automated responses (see Figure 37). The perception layer can include sensors installed in the soil to capture data on moisture, pH and nutrient levels; drones and satellites that capture detailed images of the land's topography or location of animals; sensors installed in aquaculture ponds that capture fish movement, algae levels and contamination; sensors attached to greenhouses, water pumps and cold storage facilities that allow for remote monitoring; sensors attached to farming equipment (e.g. tractors) to track their location and performance; and sensors installed in collars or harnesses worn by livestock to monitor their health and location.

Critical to the success of any smart farming solution is the accuracy of the data collected within the perception layer. If the data collected is not accurate, then the insights, recommendations and actions stemming from the data will fail to yield the operational benefits desired.

Figure 37

Examples of devices in the perception layer

Soil monitor: MimosaTEK

Smart collar: Chipsafer

Smart feeder: Eruvaka Technologies

Source: D4Ag providers

The network layer: data transmission

The network layer, also known as the connectivity layer, is responsible for transmitting data from the IoT devices capturing data (the perception layer) to the processing layer where the data is analysed via the cloud. Sensors can connect directly to the cloud if embedded with a cellular or LPWA-enabled sensor (see Figure 38). This is typical for solutions that require the installation of a single sensor, such as a water pump or cold storage solution. It may also be the architecture of choice for solutions that connect assets that are expected to move, such as mechanisation access services that might be required in one district one day and another district on another day; or connected livestock that may escape a farm or be stolen. Many current smart farming solutions, however, rely on a gateway that aggregates data from all the devices and then sends it to the cloud for analysis. Connecting a single gateway can help save overall connectivity costs, since the gateway is the only device that requires direct connectivity to the cloud.

Figure 38

IoT network configurations, with and without a gateway
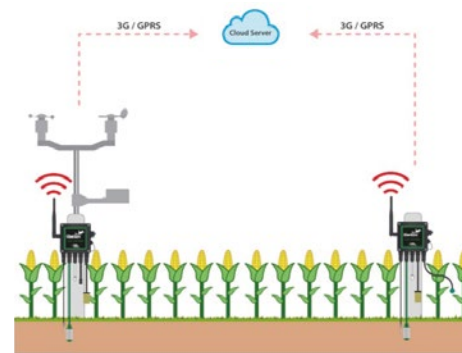
NO GATEWAY
Suitable for
- Farmers using 1–2 sensors on the premises
- Connected assets that may move outside a fixed area (such as livestock or machinery)
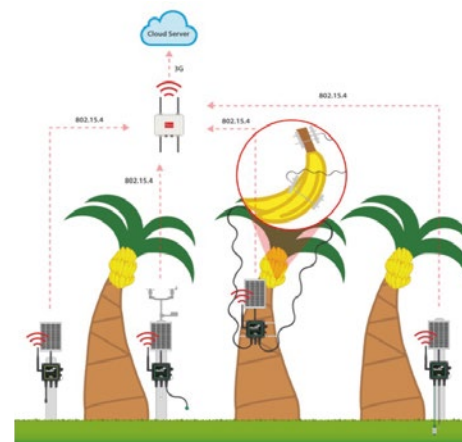
GATEWAY
Suitable for
- Farmers using multiple sensors on the premises
- Connected assets that are typically fixed or limited in movement (such as a greenhouse or storage facility)

Source: Libelium, Digital Agri Hub

The network layer: data transmission

There are a vast number of technologies available to smart farming solution providers within the network layer. IoT devices can connect to a gateway using cellular technologies (2G, 3G, 4G), licensed spectrum LPWA solutions (NB-IoT and LTE-M), unlicensed spectrum LPWA (Sigfox,[93] LoRa) or short-range technologies, such as Wi-Fi or Zigbee (see Figure 39). Some providers have even experimented with the use of TV white space. By the same token, gateways can connect to the internet using cellular technologies (2G, 3G, 4G, 5G) as well as licensed and unlicensed LPWA solutions or even satellite. D4Ag provider Skylo, for example, connects their Skylo gateways to the cloud via a satellite connection, bypassing in-country broadband networks altogether.

The connectivity solution selected is based on several factors, including the availability of different networks, the cost of data on those networks, the amount of data being transmitted and the frequency of the data transmission. Most of the solutions implemented to date in the context of smallholder farming in LMICs rely on short-range connectivity solutions between the IoT devices and the gateway, and cellular connectivity (2G, 3G or 4G) between the gateway and the cloud.

Figure 39

Different IoT network topologies in the network layer
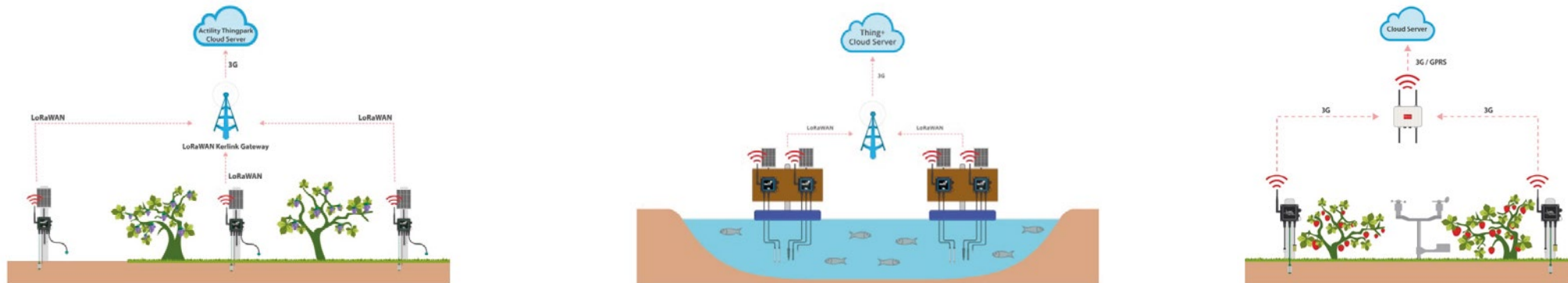
Source: Libelium, Digital Agri Hub

93 In February 2022, French-based Sigfox filed for rehabilitation in the French courts. This will allow the company to suspend payments to creditors while they seek a buyer. The company cited slow sales of their IoT solutions and difficulty accessing electronic components due to the COVID-19 pandemic for their filing. Datacenter Dynamics. (2022). IoT Startup Sigfox files for insolvency. Available at: www.datacenterdynamics.com/en/news/iot-startup-sigfox-files-for-bankruptcy/#:~:text=French%20Internet%20of%20Things%20startup,industry%20due%20to%20Covid%2D19.

The emergence of licensed LPWA technologies such as NB-IoT and LTE-M will help smart farming solutions achieve scale

Although most smart farming solutions in LMICs rely on cellular technology in the network layer, traditional consumer cellular technology is not ideally suited for machine-to-machine (M2M) connectivity given its always-on nature and high-power consumption. The scaling of smart farming applications in rural areas will therefore ultimately rely on more wide-scale availability of LPWA networks.

LPWA networks can support low-power, long-range and low-cost devices which is critical for success in the agriculture vertical. Smart farming solutions using LPWA to date have been deployed using unlicensed spectrum, relying on technologies such as LoRa and Sigfox. Only one of the D4Ag providers interviewed for this study (eFishery) has tested licensed LPWA solutions. Licensed LPWA solutions, such as NB-IoT and LTE-M, offer several key advantages, including substantial improvements in transmission ranges for wide-area deployments, better in-building penetration, reduced power consumption (enabling 10-year battery life for connected devices) and rapid deployment, as they can leverage existing mobile network assets.[94] Given the backing from MNOs, licensed LPWA solutions will benefit from a broader ecosystem, ultimately helping to drive hardware prices down.

94 See the GSMA's mobile IoT resources for more insights: www.gsma.com/iot/mobile-iot/.
95 GSMA. (2022). *Mobile IoT Deployment Map*. Available at: www.gsma.com/iot/deployment-map/.

Figure 40

Licensed mobile IoT deployments globally, 2021[95]

- ■ LTE-M
- ■ NB-IoT
- ■ Both

54	**106**	**160**
LTE-M networks	NB-IoT networks	Mobile IoT networks
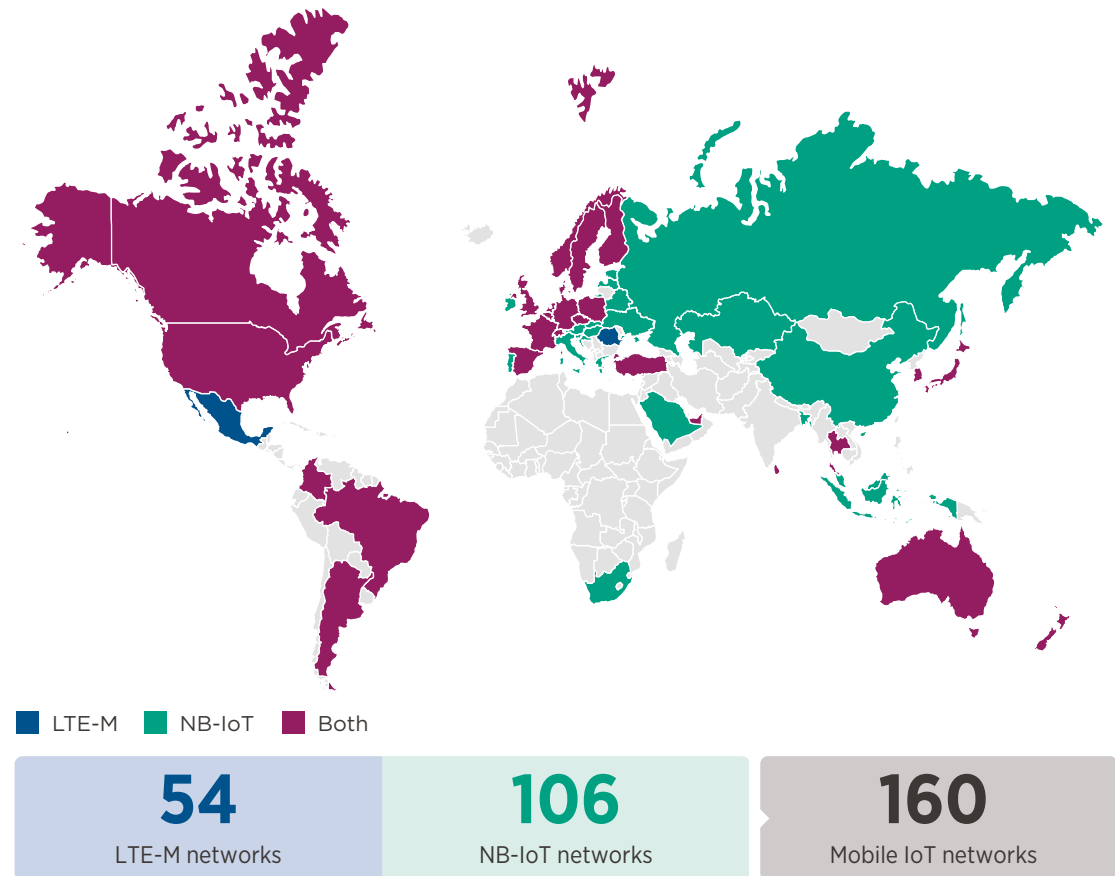
Source: GSMA IoT (accessed in May 2022)

Processing, application and implementation layers: data analytics

In the **processing layer**, also known as the middleware layer, data that has been collected by sensors and transmitted by networks is captured, stored and processed.[96] There are two main activities that take place in the processing layer. The first is **data accumulation**, which involves sorting through the thousands, if not millions, of data points and images collected by sensors, drones and satellites, and separating essential and non-essential data. The second is **data abstraction**, which involves integrating data from sensors with third-party data, reconciling the various data sources and translating the data into a format that can be used in the application layer to develop solutions suitable for the end user.[97]

In the **application layer,** data is further analysed and prepared for use by the farmer, the tractor owner, the bank or the agribusiness using the smart farming solution. This is the layer where data analytics takes place and where AI and big data can increasingly be leveraged. It is also where integration with other platforms, including mobile money, SMS and USSD, occurs.

In the **implementation layer**, also known as the **business layer**, data is presented to the end user in the form of recommendations, automated actions and services that help them achieve their business objectives. Through our research, we identified several business models that are applied in the business layer. These are discussed in more detail in the next section (Section 5).

96 BelkIoT. (n.d.). *5 Layer Architecture of IoT*. Available at: https://belkiot.in/5-layer-architecture-of-iot/.

97 Altexsoft. (2020). *IoT Architecture: The Pathway from Physical Signals to Business Decisions*. Available at: www.altexsoft.com/blog/iot-architecture-layers-components/.

5 Emerging business and operational models

Emerging business and operational models

Given the added complexity and expense associated with smart farming services, companies offering smart farming solutions have had to adjust their models in order to scale. Most started with a B2C model, selling their solution directly to farmers and taking advantage of government subsidies for the purchase of farming assets, such as irrigation systems or greenhouses (see Figure 53, page 82). Over time, however, many have evolved to incorporate PAYG, smart farming-as-a-service/subscription, tiered-pricing/freemium models or third-party monetisation of data. The Digital Agri Hub team has identified six distinct business models being used in the implementation of smart farming in LMICs (see Figure 41).

Unlike many other digital agriculture services that can take months to roll out, smart farming solutions generally take a few years to test and pilot before they are ready. This is particularly true in LMICs where companies launching smart farming solutions often oversee the design and assembly of the hardware (sensors, enclosures, etc.) to keep prices down for their smallholder clients. The learning curve for smallholders is steep, requiring more resources and time for capacity building. The onset of the COVID-19 pandemic in 2019 has further delayed the launch of many solutions. Sri Lanka's Dialog, for example, has been piloting their Saru smart soil monitoring solutions for roughly three years and plans to launch commercially sometime in 2022.[98] Telefónica Tech often tests new solutions over the span of a few years to ensure the solution is viable when commercially available.[99]

Figure 41

Six business models in use by smart farming solution providers in LMICs

| Upfront purchase or asset transfer | Pay-as-you-go (PAYG) | Smart farming-as-a-service/subscription | Freemium or tiered | Service bundling | Data or insights monetisation |
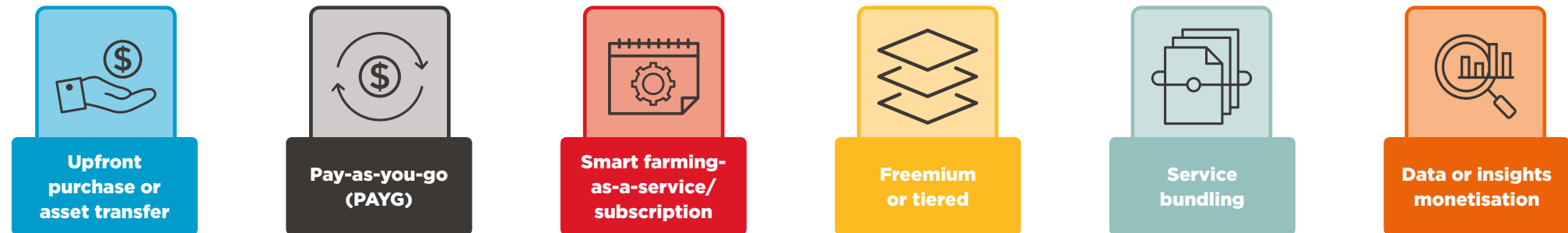
Source: Digital Agri Hub

98 The launch of the service has also been delayed as a result of the 2019 Easter bombing and the 2020-2021 COVID pandemic. Dialog interview (September 2021).
99 Telefónica interview (November 2021).

Upfront purchase or asset transfer

The earliest and most straightforward model is the upfront purchase or asset transfer model. In this model, a smallholder farmer, enterprise or NGO pays upfront for all the hardware installed onsite (sensors, gateways, etc.), as well as any monthly fees associated with ongoing data connectivity and service fees for ongoing support and advisory. The purchaser maintains ownership of the asset and is generally responsible for all maintenance fees and repairs after the initial warranty period. In some cases, data connectivity is embedded in the price of the asset for the first 12 months, after which the buyer pays a monthly data fee. Whether that fee is paid to the D4Ag provider managing the solution or to the MNO depends on whether the D4Ag provider is offering additional services that can be bundled with data access, whether they are relying on non-cellular technologies for connectivity or whether they have opted to employ international SIMs rather than SIMs from local MNOs.

D4Ag providers choosing the upfront purchase or asset transfer model can sell through B2C, B2B or B2B2C channels. The channel selected often depends on the price of the smart technology being employed. Soil sensors, for example, can be relatively inexpensive (below $200), allowing smallholder farmers to purchase these directly without necessarily requiring asset financing. Irrigated enclosure solutions, by contrast, can run up to $2,000 or more, forcing solution providers to turn to agribusinesses, cooperatives or larger farms to reach their sales objectives.

MimosaTEK, a smart irrigation company working in Vietnam, sells directly to farmers (B2C), to large agribusinesses and donors/ NGOs (B2B) and to agribusinesses that then bundle the solution with other digital solutions to offer smallholders a more holistic solution (B2B2C).[100]

100 MimosaTEK interview (September 2021).

50 per cent of Inspira Farms clients pay upfront to acquire cold storage facilities

CASE STUDY

Inspira Farms is a D4Ag provider that designs and builds energy-efficient cooling facilities (cold storage and packhouses) that are placed as close as possible to the farmgate to help horticultural farmers reduce waste and reach new markets by extending the life of their produce.[101] The company is run out of an office in Zimbabwe and has sold cold storage solutions in 15 countries to date, primarily in East and West Africa, but also in Latin America. Most Inspira Farms clients export their produce to international markets. Every

cooling facility installed since 2018 is equipped with cellular-based sensors that can measure the performance of the unit as well as relevant metrics, such as temperature, humidity and how many times the door is opened. If the door is accidentally left open, the sensor triggers an alarm to prevent post-harvest crop losses. Inspira Farms sells directly to farmers through a B2C model as well as to larger organisations, including agribusinesses, exporters and NGOs (see Figure 42).

Figure 42

Inspira Farms go-to-market business models, 2021

CLIENTS	MODELS	ONGOING SUPPORT
B2B clients Twiga Farms, World Bank/Government of Rwanda, Ausmoz Farm, Instaveg, GreenPath Food.	**Direct asset transfer** 50% of customers Clients pay 100% upfront.	Data connectivity and monitoring service provided free for the first 12 months. After that, continuous monitoring is billed at an average fee of $61 (€60) per month.
B2C Farmers, cooperatives.	**PAYG** 50% of customers Clients pay 20% upfront. The remaining 80% is financed over 12 to 60 months.	Data connectivity and monitoring service provided free for the first 12 months. After that, continuous monitoring is billed at a small monthly fee.

Source: Inspira Farms

101   Inspira Farms interview (October 2021).

PAYG model

Pay-as-you-go (PAYG) is an asset financing model whereby smart farming solution providers finance the acquisition of an asset over time, typically 12 to 60 months. The solution provider generally requires a down payment ranging from 20 to 50 per cent, with the remainder billed in monthly installments, often paid through a mobile money platform. The solution providers either extend financing themselves or team up with a financial service provider (FSP). Most assets are equipped with remote-locking technologies that allow the solution provider or FSP to interrupt service (power or irrigation) if the farmer is in arrears. The remote-locking technology provides an incentive for farmers to keep up with their payments while also reducing the cost of servicing the loans for FSPs.[102]

SunCulture is the best-known example of a D4Ag provider using the PAYG model for smart irrigation systems (they are also expanding to other solutions). Many others have employed PAYG to scale up their business, including Synnefa (formerly Illuminum Greenhouses), Inspira Farms and Hello Tractor.

Figure 43

SunCulture pricing models[103]

	Cash (Ksh.)	Depost (Ksh.)	Tenor (Months)	Monthly (Ksh.)	Total (Ksh.)
ClimateSmart™ Direct	55,000	5,999	24	2,850	74,399
Rainmaker 2C Kubwa	83,000	7,999	24	4,000	103,999
ClimateSmart™ Battery + TV	99,999	10,999	24	4,699	123,775
Rainmaker2 with ClimateSmart™ Battery	103,000	9,999	30	4,300	138,999
Rainmaker2 with ClimateSmart™ Battery + Direct Drip	122,000	10,999	36	4,300	165,799
Rainmaker2 with ClimateSmart™ Battery + TV	123,000	11,999	36	4,300	166,799
Rainmaker2 with ClimateSmart™ Battery + Direct Drip + TV	142,000	30,999	36	4,300	185,799

Source: SunCulture

102 GSMA. (2021). *Agri DFS: Emerging business models to support the financial inclusion of smallholder farmers*.
      Available at: https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2021/10/Agri-DFS-Emerging-business-models-to-support-the-financial-inclusion-of-smallholder-farmers.pdf.
103 SunCulture. (2020). Available at: https://sunculture.com/wp-content/uploads/2020/12/SKL-JUL3020.pdf.

Hello Tractor uses a PAYG model for tractor owners and cooperatives to acquire mechanisation equipment

CASE STUDY

The PAYG model is most often used to lower the barrier to entry for smallholder farmers to acquire an asset or service (demand-side). It can also be used, however, to get more assets into the hands of small business owners or cooperatives that, in turn, can lease out these assets to smallholders (supply-side). This is what Nigeria-based Hello Tractor is doing to expand the number of tractors available to smallholders via the Hello Tractor app. Tractor owners or cooperatives can make an initial down payment

(typically five per cent – see Figure 44) to secure a tractor. Tractor owners pay their outstanding balance to Hello Tractor by having $17 deducted from their fees every time they book a new job on the Hello Tractor app.[104]

These tractors then become available to Hello Tractor users in Nigeria or Kenya through the Hello Tractor app. Farmers reserve a tractor using the app and a tractor is made available within 72 hours.

Figure 44

Process for applying for a PAYG loan from Hello Tractor[105]

1 Receive training

Entrepreneurs receive training on contracting business, driver recruitment, technology and booking farmers.

2 Book farmers

Entrepreneurs with 5% down payment and 500ha of land pre-booked in the Hello Tractor app are vetted for financing.

3 Receive tractor

Approved entrepreneurs receive JD 65hp tractor with implements, technology and dedicated account manager.

4 Earn & repay

As tractors service pre-booked farms, a small loan repayment of $20 is auto-deducted to pay down loan.

Source: Hello Tractor

104 Hello Tractor: https://hellotractor.com/financing/
105 Loan applicants are not required to have 500 acres of land to qualify for a loan, rather, mechanisation equipment made available to Hello Tractor users via the Hello Tractor app must have serviced a combined 500 acres of land or more at the time of the loan application. See: https://hellotractor.com/financing/.

Hello Tractor uses a PAYG model for tractor owners and cooperatives to acquire mechanisation equipment

CASE STUDY

Figure 45

Terms of PAYG model for tractor owners in Nigeria and Kenya[106]

NIGERIA
for entrepreneurs

- 5% down
- Up to $43,000 per loan
- Prepayment of $17 for every Ha serviced
- Required 500Ha of land serviced per year
- Loan terms of 3+ years with no prepayment penalty
- Designed for individuals or coops

KENYA
for entrepreneurs & coops

- 5% down
- Up to $12,000 per loan
- Prepayment of $5 for every Ha serviced
- Required 500Ha of land serviced per year
- Loan terms of 3+ years with no prepayment penalty
- Designed for individuals or coops

Source: Hello Tractor

106 Hello Tractor: https://hellotractor.com/financing/

Smart farming-as-a-service or shared asset model

Under the smart farming-as-a-service model, the smallholder farmer gains access to an asset by paying a monthly or per-use fee to use it. Unlike the PAYG model, the smallholder farmer does not own the asset. Rather, it is owned by the solution provider, the tractor manufacturer or, in the case of the shared asset "uber" model, by a third party. The most well-known version of this model is the "tractor-as-a-service" or "shared-tractor" model currently employed by companies such as Hello Tractor, Vaya Tractor and TROTRO Tractor, among others (see Figure 25 on page 41). However, there are other variations of this model as well, including drone-as-a-service, smart irrigation-as-a-service (e.g. Seabex), cold-storage-as-a-service, smart greenhouse-as-a-service, fish feeding-as-a-service (e.g. e-Fishery) and smart livestock management-as-a-service.

Although some D4Ag providers bundle the price of the asset with the price of ongoing monitoring, advisory and/or automation in the monthly fee, some have opted to absorb the initial cost of the sensor themselves, charging the farmer only for the ongoing service. Skylo, currently in a pre-launch phase, is considering absorbing the $50 upfront cost of their satellite-powered sensor and charging farmers in India roughly $10 per month for ongoing monitoring and advisory.[107]

The monthly rent established by the D4Ag provider is critical to the success of a smart farming-as-a-service model. Through end user research, Tunisia's smart irrigation platform provider Seabex determined that smallholders would be willing to invest up to four per cent of the total cost of irrigation in a smart irrigation platform.[108] The company is currently testing several pricing models that equate to four per cent of the total cost of irrigation. Seabex is considering introducing different variations, including per production cycle fees, per hectare fees, per farm fees, monthly fees or annual fees. Many D4Ag providers using the smart farming-as-a-service model are making the same modifications to identify a viable pricing model that will enable them to scale.

107 Skylo interview (September 2021).
108 Seabex interview (November 2021).

eFishery's "feeding-as-a-service" model has enabled it to grow at an exponential rate

CASE STUDY

Indonesia's eFishery, a D4Ag solution company providing a full range of services around its IoT-powered automatic feeders to smallholder aquaculture farmers in Southeast Asia (and a former GSMA Ecosystem Accelerator Innovation Fund grantee[109]), has been offering their "feeding-as-a-service" solution since launching services in 2014. eFishery understood early on that a $1,000 to $2,000 price point for the automatic feeder was out of reach for most smallholders, which account for 95 per cent of their client base. Most farmers would opt to open a new pond before investing in an automatic feeder, regardless of the operational efficiencies derived from the technology. eFishery charges an average of $20 per month for their feeding-as-a-service solution and usually requires farmers to sign a 12-month contract. The model has helped eFishery scale. As of year-end 2021, eFishery feeders were installed in more than 110,000 ponds managed by 29,000 farmers.[110] eFishery has found that positioning themselves as a solution provider rather than a hardware company has helped to secure funding, given investor preferences for OpEx versus CapEx-based solutions. In February 2022, eFishery announced they had secured $90 million in Series C funding from Temasek, Softbank Vision Fund 2 and Sequoia Capital, among others, to help expand into the top 10 aquaculture markets.[111]

Figure 46

Growth in eFishery users, 2016–2020[112]

Hundreds
Groups of farmers have grown their business with ease with eFishery.

Thousands
eFishery's smart feeders have been installed and are in operation.

Billions
Fish and shrimp are fed with eFishery's smart feeder.

eFishery users within the last 3 years
3,025%

Feeder has been operated within the last 3 years
4,950%

180+ cities

21 provinces

◼ Now   ◼ Ongoing
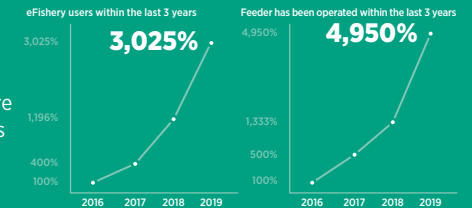
Source: eFishery

109 GSMA Innovation Fund: eFishery. Available at: www.gsma.com/mobilefordevelopment/digital-grantees-portfolio/efishery/.
110 eFishery interview (November 2021).
111 AgFunder News. (2022). Indonesian aquatech startup eFishery nets $90m in Sequoia, Softbank-led series C. Available at: https://agfundernews.com/efishery-nets-90m-for-series-c-round-aquaculture.
112 eFishery webinar. (2020). Technology to Bring the Future of Aquaculture. Available at: https://olc.worldbank.org/system/files/Slide%20World%20Bank%20Webinar%20-%20eFishery%20Oct%2015%202020.pdf.

Freemium or tiered model

With a freemium or tiered business model, solution providers offer a free or low-cost entry point for farmers. This enables them to enjoy the basic functionalities of the service while offering a path to adopt more advanced services over time. The underlying assumption is that the free or basic version of the service will help the smallholder improve performance and allow them to access financing that otherwise might not be available. Through improved performance and financing, the farmer can then access the premium version of the service. This model is most often employed by solution providers that target both large farms, usually those paying the "premium" price, as well as smallholder farmers. Generally, smart farming services are only included in the premium version of the service. Most freemium or tiered models are offered through B2C channels.

Tunisia's smart irrigation D4Ag provider Seabex, for example, offers three levels of service with increasing precision and automation. The Level 1 service uses data from satellites, soil databases, weather APIs and data inputted by farmers to generate irrigation recommendations. Level 2 incorporates a few additional databases to provide a more precise estimate while Level 3 incorporates hyperlocalised data from on-farm sensors to generate even more precise recommendations. Seabex estimates that the precision of its Level 1 solution is roughly 60 to 70 per cent while the Level 3 solution offers 90 to 100 per cent precision. Seabex's goal is to move smallholder farmers up a level every two years and achieve Level 3 precision through a sensorless solution using AI.[113]

By leveraging data gathered from various sources (IoT sensors, satellites, drones, weather and market forecasts), AI and agronomic know-how, Morocco's AgriEdge offers smallholders and cooperatives a Freemium product that includes basic crop monitoring and yield estimation at harvest. AgriEdge targets larger entities and organisations with a Premium solution that provides irrigation, fertilisation, disease management and yield prediction advisory services with the highest reliability and accuracy (see Figure 47).

Figure 47

AgriEdge pricing options, 2021[114]
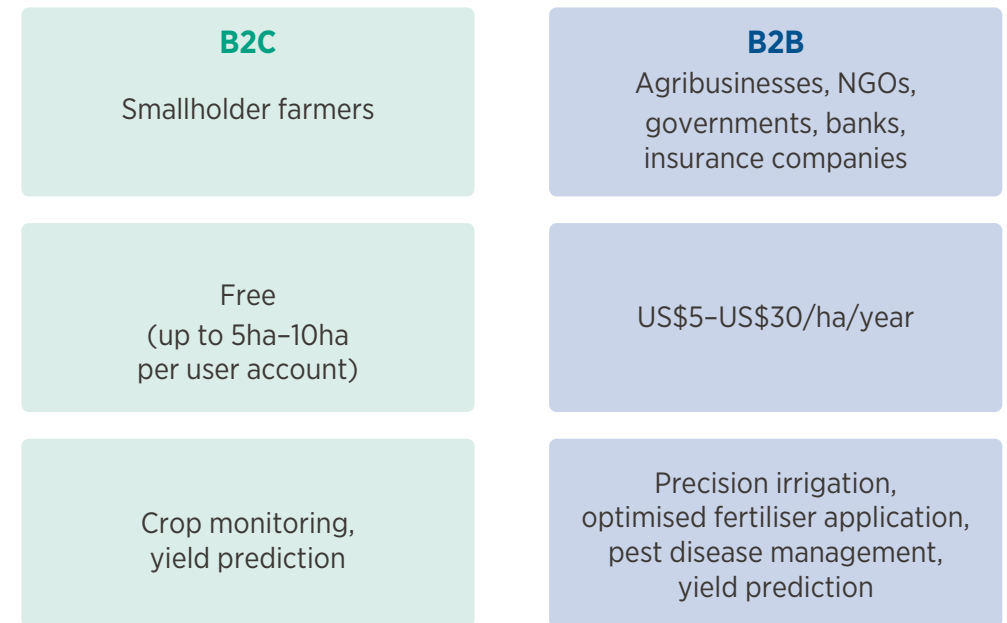
B2C Smallholder farmers	**B2B** Agribusinesses, NGOs, governments, banks, insurance companies
Free (up to 5ha–10ha per user account)	US$5–US$30/ha/year
Crop monitoring, yield prediction	Precision irrigation, optimised fertiliser application, pest disease management, yield prediction

Source: AgriEdge

JALA uses a freemium model to attract more customers to their platform and upsell higher-tier packages over time

CASE STUDY

Jala is an Indonesian D4Ag company that provides their more than 10,700 users with an aquaculture management solution that helps farmers improve operational efficiencies and incomes. The company seeks to attract users to their solution through its Basic service. As users start enjoying the added productivity associated with the management solution, JALA pitches their financial management tools, which are available at $21 per production cycle.[115] The Platinum service offers farmers a premium management solution powered by sensors at a cost of $210 per year. JALA increases revenue per client by upselling them from Basic to Premium and by adding new ponds to the platform.

Figure 48

JALA pricing options, 2021[116]

Productivity gains

SERVICE	PRICE
Basic	Free

TARGET
Farmers with 10 ponds or less

WHAT'S INCLUDED:
1 Farm management platform
2 Advisory (news, prices, diseases)

SERVICE	PRICE
Pro	$21/cycle

TARGET
Farmers with 20 ponds or less

WHAT'S INCLUDED:
1 Farm management
2 Advisory
3 Financial planning platform and tools (excel)
4 Farm stock

SERVICE	PRICE
Platinum	$210/year

TARGET
Farmers with 20 ponds or more

WHAT'S INCLUDED:
1 Farm management
2 Advisory
3 75% discount on Pro
4 Discount on smart farming sensors

Digitisation/record keeping ———————————→ **Smart farming**

Source: Jala

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115 Each shrimp production cycle is 120 to 150 days. Aquaculture farmers typically have two to three production cycles each year.
116 JALA. (2021). Available at: https://jala.tech/pricing/.

Service bundling model

1/2

Our interviews with D4Ag providers suggest that bringing smart farming technology (connected irrigation systems, cold storage, water pumps, etc.) is not enough to address farmer needs. Farmers need access to financing to acquire the technology, advisory services to maximise the benefits of their devices, procurement solutions to improve on-farm management and marketplaces to sell their crops at the highest price. Over the last few years, many of the companies interviewed have introduced additional services to provide their clients with an end-to-end solution. The COVID-19 pandemic accelerated decisions to introduce adjacent services, particularly agri e-commerce that help clients identify markets for their products.

Figure 49

Digital agriculture services offered by smart farming solution providers, 2021

	Digital advisory	Agri DFS	Agri e-commerce	Digital procurement
MimosaTEK	🟢		🔵	
Inspira Farms		🔵		
SunCulture	🟢			
Synnefa	🟢	🟢	🟢	🟢
Zenvus	🟢	🟢	🟢	🟢
AgriEdge	🟢	🔵	🟢	
Stellapps	🟢	🟢	🟢	🟢
Eruvaka Technologies	🟢		🟢	🟢

🟢 Currently offering service 🔵 Planning service launch

Source: D4Ag providers

Service bundling model

While many companies offering smart farming solutions added new capabilities (like agri e-commerce or digital advisory) to help monetise their smart farming tools, the Digital Agri Hub also identified many companies that used smart farming solutions (mainly IoT sensor-based) in support of other digital agriculture use cases, including agri e-commerce, agri DFS, digital advisory and even digital procurement. Kenya's AquaRech, for instance, had as their primary objective building a marketplace linking aquaculture farmers to input suppliers and traders and linking traders to buyers. Through the use of IoT sensors, AquaRech is helping farmers increase overall fish production, which in turn increases the volume of fish sold over the AquaRech e-commerce platform.[117] Kenya's MyFugo started out as a technology company helping smallholders manage and track their livestock. When smallholder farmers demonstrated unwillingness to pay for the technology, MyFugo switched gears and repositioned themselves as a company helping smallholders finance livestock purchases.[118]

117 Aquarech interview (October 2021).
118 Doing well by Doing Good Podcast. (2021). "MyFugo CEO Allan Tollo on Empowring Rural Dairy Farmers in Kenya".
     Available at: https://medium.com/dwdg/%EF%B8%8F-myfugo-ceo-allan-tollo-on-empowering-rural-dairy-farmers-in-kenya-8fd04b5a2c46.
119 Aquarech interview (November 2019).
120 JALA interview (November 2021).

Company	Country	Target market	Primary use case	Revenue model	Enabling smart farming technology	Adoption
AQUARECH	Kenya	Aquaculture farmers, input (feed) suppliers, traders, buyers	Agri e-commerce (inputs and outputs)	Mark-up on the sale of inputs and fish sold over the platform	Farmers can pay ~$45 (in addition to monthly data fees paid directly to the data provider) to acquire a sensor for each pond. The sensor relies on a Sigfox IoT network operated by Liquid Technologies in Kenya. Data collected from the pond helps farmers optimise feed use, reduce fish deaths and increase production.	As of year-end 2021, 200 of AquaRech's 1,500 farmers (~13%) were using IoT sensors in their ponds.[119]
JALA BARUNO	Indonesia	Aquaculture farmers	Digital advisory (record keeping and farm management)	Fremium model. Aquaculture farmers with up to 10 ponds access the platform for free. Larger farms pay up to $200 per year.	IoT sensors (Baruno) installed in ponds can automate the data collection that would otherwise be inputted by farmers into the digital platform. JALA charges ~$2,000 for the sensor, a 100% mark-up over the production cost. Farmers using the sensors can optimise labour, reduce FCR ratios and improve production.	Only ~100 of JALA's 10,700 customers (1%) have purchased the IoT sensor.[120] These are mainly larger farmers managing 20 ponds or more. Since they are focused on achieving scale, JALA is not prioritising the sale of their IoT sensors.
MYFUGO	Kenya	Livestock farmers	Agri DFS (credit and loans)	Interest and service fees collected from loans and microcredit extended to livestock farmers	Smart collars are provided to farmers to help them monitor the health of their livestock. Improved on-farm performance gives farmers a better chance of repaying the loan.	Not available

Source: AquaRech, JALA, MyFugo

Data or insights monetisation model

None of the D4Ag companies identified for this study relied exclusively on the data or insights monetisation model. Rather, many of the D4Ag companies interviewed perceived this model as a way to generate additional revenue from data they already collected through their core business by packaging it for sale to a new (typically B2B) channel. Smart farming solutions rely on the collection of thousands of data points that are then used to generate recommendations for farmers on feeding, irrigation or other farming activities. These same data points can also be useful for FSPs to assess the creditworthiness of a farmer seeking a loan, for input suppliers seeking to better understand the performance of their fertilisers or fish feed or for a tractor manufacturer that wants to improve the performance of their equipment. The data and insights monetisation model can be enabled through AI, big data and machine learning.

Figure 50

The data and insights monetisation model

Data and insights

Financial service providers

Data collected from on-farm sensors can help farmers generate a digital identity that they can then leverage when applying for credit.[121]

Insurance companies

Data collected from on-farm sensors can help insurance companies assess the risk of insuring a smallholder farmer. It can also minimise the need for onsite visits.

Input suppliers

Input suppliers can gain real-world data on the performance of various seeds, fertilisers, pesticides and fish feed, which they can then use to market their products better.

Farm equipment manufacturers

Sensors installed on farm equipment (like tractors) can provide manufacturers with real-time data on performance, which they can then use to improve their products or for marketing purposes.

Source: Digital Agri Hub

121 GSMA. (2020). *Digital credit scoring for farmers: Opportunities for agritech companies in Myanmar*. Available at: www.gsma.com/mobilefordevelopment/wp-content/uploads/2020/02/Digital_credit_scoring_for_farmers_Opportunities_for_agritech_companies_in_Myanmar.pdf.

Data or insights monetisation model

GSMA

CASE STUDY

zenvus

Zenvus is a Nigeria-based D4Ag provider that aims to help smallholder farmers improve their yields by using data collected from proprietary sensors and cameras to provide a range of services to farmers, including farm management tools, pricing information and market linkages. Zenvus also uses data from their sensors and cameras to help smallholder farmers secure loans and insurance products from FSPs (see Figure 51).

Figure 51

Zenvus' zCapital and zInsure services[122]
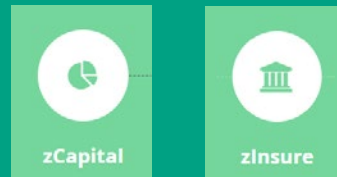
zCapital   **zInsure**

What it is

zCapital is an agro lending marketplace linking farmers, lenders and investors.

zInsure is an agro insurance marketplace linking farmers and insurers.

How it works

1 Using data from Zenvus sensors and/or cameras, farmers create a business plan (zCapital) or insurance request (zInsure) using a Zenvus-provided template, which they can then upload to the Zenvus portal for free.

2 Zenvus receives the business plans and insurance requests and validates the data in the forms with the data collected from their sensors/cameras.

3 Lenders, insurers and/or brokers pay an annual subscription fee to have access to the portal. Lenders can review the business plans and connect with the farmers to issue loans.

4 The financial transaction (loan or insurance policy) occurs off the portal and does not involve Zenvus.

122 Zenvus. (2022).
Available at: www.zenvus.com/services/zcapital/.

Source: Zenvus

Each business model has several key advantages and disadvantages

1/3

Direct purchase or asset transfer

+ Farmers pay upfront, **minimising the financial exposure** of the solution provider. Well suited to larger farmers, agribusinesses or NGOs that can pay upfront. Also suitable for cooperatives that can aggregate demand and distribute the cost across their various members.

+ Allows the **operational focus** of the solution provider to remain squarely on the performance of the smart farming solutions.

– Companies adopting this model are often perceived as hardware companies rather than solution providers, making it **difficult to raise capital.**

– The need to secure credit makes it **more difficult for women and young farmers** to acquire assets.

– **The cost of some solutions, particularly greenhouses and cold storage**, can be out of reach for many smallholders, making it difficult to achieve scale in LMICs.

– **Smallholders often have to absorb unexpected expenses** related to maintenance and spare parts.

PAYG

+ By paying for an asset over 12 to 60 months, **smallholders gain access to productive agricultural equipment** they might otherwise not be able to afford.

+ Helps farmers establish credit, which they can later use to take out larger and longer-term loans.

+ Unlike the smart farming-as-a-service model, the smallholder **fully owns the asset** (solar pump, irrigation system, greenhouse, cold storage solution) once all installments have been paid.

– Unless the solution provider teams up with an FSP, the solution provider will take on most of the credit risk.

– As with the direct asset transfer model, **smallholders often have to absorb unexpected expenses** related to maintenance and spare parts.

– Generally less suitable for D4Ag providers selling lower-cost farm assets (e.g. soil monitoring or livestock sensors).

Each business model has several key advantages and disadvantages

Smart farming-as-a-service

Advantages	Disadvantages
+ **Smallholders gain access to productive assets** (tractors, irrigation systems, aquaculture sensors) that they might otherwise not be able to afford.	**−** Particularly with the shared asset "uber" model, **the asset is not always available at the right time or in the right place**.
+ The smart farming-as-a-service model is OpEx-intensive as opposed to CapEx-intensive, **which many farmers find advantageous, and many investors prefer**.	**−** The solution provider (or asset owner in the shared asset model) is responsible for training and ongoing maintenance of the assets.
+ Mechanisation equipment owners can **monetise their assets when not in use** through the shared asset "uber" model.	**−** The smallholder farmer **never owns the asset**.
+ Helps farmers establish credit, which they can later use to take out larger and longer-term loans.	

Freemium or tiered

Advantages	Disadvantages
+ Having a no-cost or low-cost entry-level option helps solution providers **expand their target market** and achieve scale. This can benefit D4Ag providers that have opted to monetise data and insights (the more farmers on the platform the more valuable the insights) or plan to target agribusinesses, governments or NGOs through a B2B2C model.	**−** Solution providers may have **several target markets**: the smallholders that benefit from the free or low-cost option and the large farms, agribusinesses or NGOs that often fund the premium version of the service.
+ With the freemium model, smallholder farmers can test the solution before making a financial commitment.	**−** Those using the "free" version of the service are often the ones that require the most support with training and ongoing customer service.

Each business model has several key advantages and disadvantages

Service bundling

+ **Holistic solutions** that address multiple challenges are more appealing to smallholder farmers than solutions that address a single challenge.

+ ARPUs and margins can be higher for solution providers as they are capturing a **larger wallet share**.

+ **Fosters client loyalty** by making it more difficult for farmers to stop or switch services.

+ Makes it easier to guarantee long-term ownership of the farmer relationship.

− **High level of complexity** as the solution provider has to manage a broad portfolio of services and multiple partnerships.

− If the D4Ag provider develops each service internally, rather than through partnerships, this **can require significant capital**.

Data or insights monetisation

+ Gives D4Ag solution providers another avenue to generate revenue from data already being generated to power the smart farming solution.

− As more data privacy laws are enacted, **conflicts over data ownership** may emerge.

− **Solution providers may be easily disintermediated** if data is the only added value.

− Requires service providers to invest in sales to target new types of customers (B2B) and in repackaging data and insights to appeal to them.

− May be challenging for FSPs to implement.

The role of subsidies

Like other providers of digital agriculture services, smart farming solution providers have found that smallholders struggle with the ability to pay (ATP) for services even when they have the willingness to pay (WTP). In addition to the cost of ongoing service/monitoring, farmers must also pay for the hardware required to collect the data that subsequently powers the services.

Smart farming solution providers often look to third parties to partially or fully offset the cost of the solution for smallholder farmers (see Figure 52). While subsidies can help D4Ag providers increase adoption of their solution, they can also create distortions in the marketplace because they can create an expectation among smallholders that services should be free. This makes it virtually impossible to introduce fees later and can create disruptions for investors.[123] In addition to promoting operational efficiencies, third parties also may be motivated by a desire to support solutions that conserve scarce resources such as water, that promote usage by underserved groups such as women and young people or that drive climate resilience.

Figure 52

Motivations of different organisations to subsidise the acquisition of assets by smallholder farmers

		Description	Motivations	Example
	Government	Governments often provide subsidies to smallholder farmers as an incentive to increase productivity and build climate resilience. In most LMICs, subsidies ranging from 20 to 50 per cent are provided on solutions like solar water pumps, irrigation systems, mechanisation equipment and greenhouses, among others (Figure 53).	• Increase productivity among smallholder farmers • Alleviate poverty and malnutrition in rural communities • Promote import substitution by increasing production and/or reducing waste • Conserve scarce resources • Support climate resilience	• In Vietnam, MimosaTEK's clients often receive government subsidies equivalent to 30 per cent of the total price of the solution.[124] • In Togo, SunCulture has tapped into a government subsidy programme that covers up to 50 per cent of the cost of a solar-powered irrigation solution for farmers.[125]

123 Wageningen University & Research. (2016). *The impact of taxes and subsidies on crop yields*.
Available at: www.researchgate.net/publication/318495318_The_impact_of_taxes_and_subsidies_on_crop_yields_-_Agricultural_price_distortions_in_Africa.
124 MimosaTEK interview (September 2021).
125 SunCulture interview (September 2021).

The role of subsidies

Figure 52

Motivations of different organisations to subsidise the acquisition of assets by smallholder farmers

		Description	Motivations	Example
	Agribusinesses and cooperatives	Agribusinesses and cooperatives looking to increase smallholder productivity may opt to partially or fully offset the cost of the solution. In some cases, the agribusiness or cooperative will pay for the hardware that needs to be installed and require the smallholder to pay for the ongoing service.	• Increase productivity among smallholder farmers • Increase crop quality • Collect data that helps with traceability requirements • Meet sustainability objectives • Conserve scarce resources	• Coffee company Juan Valdez Café is assessing the acquisition of Telefónica's Smart Agro 4.0 solution for their smallholder coffee farmers in Colombia.[126]
	Donors or NGOs	D4Ag providers often team up with donors or NGOs when launching a new product or expanding into new areas	• Alleviate poverty and malnutrition in rural communities • Increase productivity among smallholder farmers • Conserve precious resources • Drive climate resilience • Promote the use of technology among underserved groups, like women and young people.	• The Inter-American Development Bank (IDB) is providing funding for Piscifactoria de los Andes to install Umitron aquaculture sensors in Lake Titicaca in Peru through a grant of $500,000 and subordinated loan of $1.5 million.[127]

126 Telefónica. (2021). Smart Agro Perú: Una Alianza De Telefónica, FAO y Brasil, Contribuyendo para +Algodón.
Available at: https://iot.telefonica.com/es/whats-new/news/smart-agro-per%C3%BA-una-alianza-de-telef%C3%B3nica-fao-y-brasil-contribuyendo-para-plusalgod%C3%B3n/.
127 Inter-American Development Bank. (2018). Internet of things to improve productivity and sustainability of trout aquaculture in Peru.
Available at: www.iadb.org/en/news/internet-things-improve-productivity-and-sustainability-trout-aquaculture-peru.

The role of subsidies

Figure 52

Motivations of different organisations to subsidise the acquisition of assets by smallholder farmers

		Description	Motivations	Example
	Financial service providers (FSPs)	FSPs, such as credit lending and insurance companies, are increasingly looking to pay for sensors on their smallholder clients' plots to collect data that will help them monitor performance and refine lending and insurance algorithms. Although still in very early stages, it is expected that the data collected will help FSPs better understand smallholders and make it more viable to serve them.	• Improve the performance of credit and insurance products by having a better understanding of farmer activities • Improve productivity to give farmers a better chance of repaying a loan • Support climate resilience to minimise the need for insurance payouts	• Synnefa (formerly Illuminum Greenhouses), worked closely with APA Insurance on the design of their latest-generation dashboard to ensure that the data captured is aligned with APA's requirements.[128]
	Corporations or high-net individuals	Large corporations with unavoidable emissions fund initiatives that are proven to offset their carbon emissions through greener practices. They pay into marketplaces such as the Verra Standard or Gold Standard. Some companies have recently started looking into carbon offsets as a way to lower the cost of smart farming solutions for smallholders.	• Meet corporate sustainability objectives (typically annual net-zero emissions)	• Kenya's SunCulture is exploring the possibility of seeking funding from these carbon offset marketplaces to lower the cost of their solution for smallholder farmers.[129]

128 Synnefa interview (October 2021).
129 SunCulture interview (September 2021).

Government subsidies for agricultural assets

Figure 53

Examples of government subsidies for smallholders to acquire agricultural assets

Tunisia	According to the 2016 Investment Law, the Tunisian government offers smallholder farmers subsidies of up to 50 per cent on the acquisition of agricultural equipment, such as irrigation systems.[130]
India	India's government offers farmers a subsidy of up to 55 per cent on drip irrigation and sprinkler systems as part of its "Per Drop More Crop" scheme aimed at conserving water and supporting smallholder farmers.[131] In Punjab, farmers are eligible for subsidies of up to 90 per cent for drip irrigation systems.[132]
	The National Horticultural Board offers subsidies of up to 50 per cent for the acquisition of greenhouses, up to $700. In addition, farmers may be eligible for additional subsidies from their local governments (15 to 25 per cent depending on the state).[133]
Vietnam	The Vietnamese government offers subsidies of up to 30 per cent for the acquisition of irrigation systems.[134]
Togo	In an effort to reduce their carbon footprint, the Government of Togo introduced subsidies in 2019 for off-grid solar pumps and solar-powered irrigation systems.[135] The government also launched Yolim in 2020 to help smallholder farmers acquire mechanisation assets (see case study, page 83).

Source: Local governments, D4Ag providers

130 Oxford Business Group. (2019). Government programmes and private investment boost efficiency and equity in Tunisia's olive oil segment. Available at: https://oxfordbusinessgroup.com/overview/green-shoots-government-programmes-and-private-investment-sector-improve-irrigation-and-boost.

131 Pradhan Mantri Krishi Sinchayee Yojana. (2017). Operational Guidelines of Per Drop More Crop. Available at: https://pmksy.gov.in/microirrigation/Archive/GuidelinesMIRevised260417.pdf.

132 Express News Service. (22 October 2021). "Move to save groundwater: Punjab to provide subsidy up to 90% for drip irrigation". The Indian Express. Available at: https://indianexpress.com/article/cities/chandigarh/punjab-drip-irrigation-subsidy-ground-water-7585627/.

133 Krishi Jagran. (2021). Greenhouse farming loans: Govt. subsidies and method to apply. Available at: https://krishijagran.com/agripedia/greenhouse-farming-loans-govt-subsidies-and-method-to-apply/.

134 MimosaTEK interview (September 2021).

135 International Solar Alliance. (2019). "Togo launch[es] first ever subsidy for Offgrid Solar to accelerate energy transition and solar adoption." Available at: https://isolaralliance.org/search?q=togo.

Togo's Yolim programme subsidises access to agricultural equipment for smallholder farmers

CASE STUDY

In 2020, Togo's Ministry of Agriculture, in collaboration with financial institutions and MNOs Togocel and Moov, launched Yolim, an interest-free loan programme for smallholder farmers to acquire inputs at any of 209 authorised distributors. Through an agreement with the Togolese government, Vaya/TROTRO have made 122 tractors available to smallholder farmers.[136] More than 57,483 farmers have applied for loans through the programme.[137]

Figure 54

Overview of Togo's Yolim programme

USSD code *820#

USSD code *824#

STEP 1

Via USSD, the farmer applies for a Yolim loan. To qualify, they must grow a high-value crop as defined by the government (soy, cashew, cotton, maize, rice, millet), have a voter card, a mobile number and be affiliated with an approved aggregator.

STEP2

The farmer receives an interest free-loan from Yolim via mobile money equivalent to FCFA 96,000 ($196). This is transferred to electronic vouchers called YLMs at a rate of FCFA 1,000 ($1.68): 1 YLM.

STEP 3

The farmer can use YLMs at any of 209 authorised dealers to acquire inputs. They can also access one of 122 tractors available through Vaya/TROTRO using the USSD code *824#.

STEP 4

The authorised aggregator affiliated with the farmer will pay back the loan with the funds generated from the farmer's sale of the crop.

Source: Yolim

136 Commodafrica. (2020). "Yolim, le crédit numérique à taux zéro pour les agriculteurs lancé au Togo."
Available at: www.commodafrica.com/29-07-2020-yolim-le-credit-numerique-taux-zero-pour-les-agriculteurs-lance-au-togo.
137 LinkedIn. (2020). "Yolim – a digital, interest-free loan programme to improve yields and livelihoods of Togolese farmers."
Available at: www.linkedin.com/pulse/yolim-digital-interest-free-loan-programme-improve-yields-cina-lawson/.

6 Mobilising investment in smart farming

Key opportunities and recommendations

Key findings

After reviewing more than 70 different smart farming services available to users in LMICs and mapping them against our D4Ag solution assessment framework, the Digital AgriHub team had several key findings:

1 **Smart crop management solutions account for the largest share of smart farming solutions available in LMICs today.** Within the smart crop management category, solutions that address smallholder challenges with irrigation are highest in number, but have struggled to attract investment and achieve scale.

2 **Most of the solutions analysed deliver on the D4Ag solution assessment framework priority of higher productivity and well-being.** Very few of the solutions analysed make a deliberate effort to be inclusive (e.g. target women or young people). More work needs to be done to ensure that smart farming solutions bridge, rather than widen, the gender income gap in rural communities in LMICs.

3 Although many of the solutions analysed can help build resilience to climate events by enabling farmers to conserve resources or work their land more productively, very little data is being collected on the ability of smart farming to deliver on this D4Ag solution assessment framework priority. One possible exception is Telefónica, which found that farmers involved in their smart farming pilot in El Salvador did not suffer any crop losses during climactic events, in contrast with neighbouring farms that did not participate in the pilot and experienced significant losses during the same events.[138]

138 Telefónica. (2021). *Smart Agro Perú: Una Alianza De Telefónica, FAO y Brasil, Contribuyendo para "+Algodón".*
Available at: https://iot.telefonica.com/es/whats-new/news/smart-agro-per%C3%BA-una-alianza-de-telef%C3%B3nica-fao-y-brasil-contribuyendo-para-plusalgod%C3%B3n/.

Opportunities in smart farming

Given the nascent stage of smart farming in LMICs, much of the data collected on the performance of smart farming solutions has been self-reported rather than independently verified. Nevertheless, this early reporting is promising and illustrates how smart farming solutions can help smallholder farmers in LMICs dramatically improve productivity while reducing their overall operating costs, positively impacting incomes. Based on these early results, we remain optimistic that smart farming solutions represent a potentially attractive opportunity for investors, donors and other agriculture industry stakeholders seeking to scale digital solutions that could improve productivity and farmer livelihoods in LMICs. **Smart farming solutions offer smallholder farmers the tools they need to become more productive, while also strengthening their resilience to one-time shocks and the effects of climate change. Data collected through smart farming solutions also helps drive financial inclusion in rural areas, which can help local economies in LMICs become more resilient.**

Despite their potential, there are many pitfalls associated with the roll-out of smart farming solutions in LMICs. This is due to their relative complexity compared with other digital agriculture solutions, as well as their higher implementation costs. To help industry stakeholders avoid these pitfalls while also maximising the potential, scale and sustainability of smart farming solutions, members of the Digital AgriHub initiative have examined (1) the markets that have the most potential; (2) the business models that hold the most promise; and (3) the roles that different ecosystem partners can play.

Market prioritisation

Investors and donors need to understand local market dynamics and how they will affect the deployment of different smart farming solutions. By "market", we are referring not only to countries, but also market segments (e.g. cash crops versus aquaculture versus fresh produce). The success of a solution in one market does not necessarily translate into success in another. As Figure 12 on page 29 illustrates, the same smart crop management solution can increase yields in one value chain (bell peppers) by 20 per cent, while another can see only a five per cent improvement (rice).

When assessing the same solution in different countries, we found that government regulations, the state of a value chain and competitive dynamics can all play a major role (see Figure 55). Government subsidies for irrigation systems or mechanisation equipment that might make a smart farming solution affordable in one market may not be present in another, putting the same solution out of reach for a smallholder farmer with a similar income profile. A robust mobile money ecosystem can underpin the success of a shared tractor service in an African market, while the same service may have difficulty getting off the ground in a Latin American market due to cultural differences and a lack of mobile money infrastructure. Heavy import restrictions on IoT sensors or limited local assembly capabilities could also raise the price of the solution above what farmers can afford. Limited availability of NB-IoT networks may also limit the ability of a solution to scale.

Market prioritisation

Figure 55

D4Ag providers adapt their strategies to different markets

Inspira Farms found that they needed to adjust their strategy when moving from East Africa to West Africa and from Africa to Latin America:[139]

1 In West Africa, a less-mature ecosystem led Inspira Farms to align their go-to-market strategy accordingly.

2 A "pay-as-you-chill" model that worked in Africa did not translate to Latin America.

3 In Senegal, Inspira Farms developed an import substitution strategy to align with the government's priority to replace potato imports with local production.

SunCulture adapted their strategy based on the market it was seeking to enter:[140]

1 In Togo, they opted to work through a government initiative aimed at helping smallholders access irrigation equipment (B2G2C strategy).

2 In Côte d'Ivoire, they pursued a direct-to-consumer strategy (B2C) instead.

139 Inspira Farms Interview (October 2021).

140 SunCulture Interview (September 2021).

Market prioritisation

For investors looking at cold storage solutions, Sub-Saharan Africa and Latin America may provide more opportunity given the higher proportion of waste in the "storage" stage of the food chain (see Figure 56). Investors assessing aquaculture solutions, by contrast, may opt to prioritise South Asia, Southeast Asia and Latin America given the expected growth in the aquaculture industry in those markets over the next 10 years (see Figure 57).

141 Bayer and Handelsblatt Research Institute. (n.d.). *The Future of Agriculture and Food: Facts and Figures.* Available at: www.bayer.com/sites/default/files/factbook.pdf.

142 Nature, Ecology and Evolution. (2017). *Mapping the global potential for marine aquaculture.* Available at: www.nature.com/articles/s41559-017-0257-9.

Figure 56

Food losses sustained at various stages of the food chain, by region[141]

Production → Storage → Processing → Retail → Consumers

Percentage of kcal lost or wasted worldwide

Sub-Saharan Africa
Latin America
South/Southeast Asia
North Africa, Western/Central Asia
Asia (industrialised countries)
Europe
North America/Oceania

0%   20%   40%   60%   80%   100%

Source: Bayer, WRI

Figure 57

Expected future growth in aquaculture production globally[142]

A

Current production
(tonnes ×10^3)

- 0–1
- 1–500
- 500–1,000
- 1,000–2,000
- 2,000–4,000
- 4,000–8,000
- 8,000–12,000

B

Potential production
(tonnes ×10^3)

- 0–1
- 1–500
- 500–1,000
- 1,000–2,000
- 2,000–4,000
- 4,000–8,000
- 8,000–16,000
- 16,000–24,000

Source: Nature, Ecology & Evolution

Business models with most potential to scale

To date, the smart farming services that have had the most success achieving scale are those that rely on the PAYG or smart farming-as-a-service model. These business models lower the barrier to entry for smallholder farmers, while creating an ongoing relationship that allows the D4Ag provider to maintain control of the farmer relationship and upsell new services over time. Companies like eFishery (smart farming-as-a-service) and SunCulture (PAYG) have successfully adopted these models to increase their user numbers and attract the attention of investors (see Figure 58). To successfully execute these models, however, D4Ag companies must either be sufficiently funded to extend financing to smallholders themselves or they must team up with a financial institution able to provide financing.

Figure 58

eFishery funding rounds, 2014–2022

	Seed round	Series A	Series B	Series C
	2014	**2018**	**2020**	**2022**
Amount raised	**$750,000**	**$4 m**	**$20 m**	**$90 m**
Investors	Aquaspark	Aquaspark	Go Ventures	Softbank
		Wavemaker Partners	Northstar Group	Temasek
		500 Startups	Aquaspark	Sequoia
		Malaoke Ventures	Wavemaker Partners	
		Unreasonable Capital		
		Triputra Group		
		Social Capital		

Source: eFishery

The importance of partnerships

Smart farming services entail a wide range of activities, from designing and assembling sensors and other hardware to platform/algorithm design, farmer acquisition and training, financing, ongoing service support and product maintenance, logistics and others. Not only is it expensive to take on all these tasks, it can also be complicated given the array of skills and expertise required. Costs can be minimised by engaging with external partners. The Digital Agri Hub team sees six potential partnership opportunities for smart farming solution providers.

1

Other D4Ag providers, particularly those providing agri e-commerce solutions

Most smart farming solution providers interviewed for this study have found that providing smart farming is not enough. Smart farming must also often be bundled with agronomic advisory to ensure that solutions are implemented correctly and achieve the promise of higher productivity and lower costs. In some cases, smart farming can support other use cases, such as digital procurement or agri DFS. Because increased production does not benefit farmers unless they can find a market for their products, virtually all the D4Ag providers interviewed for this study had either already launched, or were in the process of launching, agri e-commerce platforms. Rather than develop these additional capabilities from scratch, there is an opportunity for smart farming solution providers to team with other D4Ag providers with expertise in these other use cases. There is also an opportunity for agri e-commerce companies in particular to seek out partnerships with smart farming solution providers to identify new sources of produce for their sites. Twiga Farms, for example, is testing IoT technology on one of their farms to boost the production of farmers selling on their agri e-commerce platform.[143] They could seek to partner with an already established remote crop management solution provider to accelerate time to market.

143 Liquid Intelligent Technologies. (2020). *Liquid Intelligent Technologies partners with Twiga Foods to accelerate agricultural transformation in Kenya*. Available at: www.liquid.tech/about-us/news/Liquid_Intelligent_Technologies_partners_with_Twiga_Foods_to_accelerate_agricultural_transformation_in_Kenya.

The importance of partnerships

2

Agribusinesses and cooperatives

Agribusinesses and cooperatives have had minimal involvement in the development of smart farming solutions for smallholder farmers in LMICs. This is, in part, because most of the smart farming solutions implemented to date have been in fresh produce, livestock and aquaculture value chains, which are not as highly structured as value chains like coffee and cocoa where the cost-benefit analysis of implementing smart farming solutions has been more difficult. There is an opportunity for smart farming solution providers to work more closely with cooperatives and agribusinesses, particularly given their greater ability to pay for the solutions upfront and to aggregate demand. MimosaTek, for example, has been working with ECOM's Vietnam division to include their smart irrigation solution in a wider service for their farmers. Their "farming-as-a-service" package includes irrigation, seeds, fertilisers, pesticides and other farm assets that are bundled together and paid for monthly through the cooperative.[144]

144 MimosaTEK interview (September 2021).

3

Financial service providers

Given the upfront cost of many smart farming solutions, asset financing is often required to help smallholder farmers access the solution. In some cases (e.g. SunCulture), the financing is provided by the D4Ag provider itself, although this may be difficult to maintain as the solution scales. In most cases, the D4Ag provider is unable to take on the financing and instead teams with FSPs that have this capacity as well as experience with rural customers. With more and more D4Ag providers experimenting with PAYG and smart farming-as-a-service models, partnerships with FSPs will become even more critical to achieving scale. D4Ag providers bring more than potential new customers to the table. They also generate thousands of data points related to on-farm activities that FSPs can use to refine their algorithms and improve the outcomes of their credit and insurance products. Synnefa's partnership with APA Insurance is a prime example of the benefits D4Ag providers can realise from teaming with FSPs (see Figure 52, page 81).

The importance of partnerships

4

MNOs

With a few notable exceptions, including Telefónica, Dialog and Econet, MNOs have not played a particularly active role in the roll-out of smart farming services, choosing instead to play a supporting role when involved. Bangladesh's Grameenphone, for instance, transferred their smart farming pilot projects to start-up iFarmer to execute. This reticence is due to the complexity of operating smart farming services in rural areas. Many D4Ag providers interviewed for this study had found it difficult to engage local MNOs and instead worked with international IoT-SIM providers like Hologram to power their smart farming solutions. There is an opportunity, however, for MNOs and MMPs to leverage their technology, digital platforms, marketing and sales and connectivity assets to play a bigger role in the development of smart farming solutions. Teaming with smart farming solution providers offers MNOs an opportunity to monetise part of their investment in the roll-out of new NB-IoT and LTE-M networks.

5

Asset manufacturers/ retailers

There is an opportunity for D4Ag providers to embed their IoT-based solutions in the solutions of farm asset manufacturers. In Zimbabwe, Vaya Tractor has been looking at teaming with local agricultural machinery manufacturing company, William Bain, to ensure a more reliable and robust fleet for their shared tractor platform.[145] Hello Tractor discussed a partnership with John Deere and the Nigerian government that would have equipped 10,000 John Deere tractors with their GPS devices and software, creating a ready market for Hello Tractor's asset-sharing services.[146] Although in the end the Hello Tractor/John Deere partnership did not materialise, we believe these types of agreements hold promise. D4Ag companies providing smart irrigation, greenhouse and cold storage solutions could seek to do the same, teaming with manufacturing companies or distributors selling these solutions to embed them with IoT sensors.

145 All Africa. (2019). *Zimbabwe: Vaya Tractor Seals Strategic Partnerships*. Available at: https://allafrica.com/stories/201912110198.html.

146 Peters, A. (29 August 2018). "This startup lets African farmers hire an on-demand tractor to boost their harvests". *FastCompany*. Available at: https://www.fastcompany.com/90227534/hello-tractor-and-john-deere-bring-10000-tractors-to-Africa.

The importance of partnerships

6

Sensor/ hardware design, manufacturing and assembly

Most of the D4Ag providers interviewed for this study found off-the-shelf solutions either too expensive or too complex for their target smallholder customers, not to mention challenging to import into the country. As a result, most of the companies were involved in the design of their own sensors and hardware to reduce the cost and meet the needs of local smallholders. Activities ranged from design to procuring parts, finding partners for local assembly and sourcing compatible SIM cards. Associations like Africa Goes Digital that help digital agriculture providers in LMICs share best practices can play a role in aggregating demand. There may also be an opportunity for investors to broker discussions between several smart farming D4Ag providers to develop hardware that can be utilised by more companies and use cases, thereby creating the economies of scale needed to bring down device prices.

Recommendations for investors, donors and D4Ag providers in the smart farming ecosystem

The Digital Agri Hub team has developed a set of recommendations to support funding, product development and marketing for key stakeholders in the smart farming ecosystem, including D4Ag companies, donors and investors.

RECOMMENDATION #1

Do not expect immediate returns on investment.

Many investors are likely to associate investment in D4Ag with risks in the agricultural sector at large. There is a need for greater awareness among investors of the benefits technology can bring to the agricultural sector, particularly small-scale agriculture in LMICs. Providers of smart farming solutions should aim to educate investors about their unique business proposition, and the D4Ag sector in general, before demonstrating the opportunity for both sides to benefit from the investment. Such engagement may take time, particularly with smart farming solutions, since services often need to be tested for several years before they can launch commercially. Donors, often the earliest to invest in D4Ag companies offering smart farming solutions, may need to take a longer-term view than their typical three-year cycle. Patient capital from early investors will make it easier for D4Ag providers with smart farming solutions to attract additional investors and scale their business.

Recommendations for investors, donors and D4Ag providers in the smart farming ecosystem

RECOMMENDATION #2

Ensure that services are designed to solve specific smallholder farmer challenges.

Human Centred Design (HCD), or user-centred design, involves designing products and services around user needs and preferences, identifying the most suitable technology to deliver them and implementing a viable marketing and pricing strategy to target different users. HCD ensures that users are engaged at every step of product development, from early stages of identifying opportunities and generating concepts, to advanced stages of product realisation, execution and scaling.[147] By involving smallholders directly in the product development phase, D4Ag providers can maximise their chances of success. There is an important role for investors and donors to play in urging smart farming providers to put users at the centre of their product design, particularly when those users (e.g. women and the disabled) may be left behind. Google, for example, provided funding to AquaRech in Kenya with the expectation that they would take deliberate steps to understand the needs of female aquaculture farmers, train them and ensure they were well represented among their users (see page 50).

seabex

Seabex's founders wanted to address the impact of climate change in Tunisia and developed an IoT-based solution for more efficient water use. However, the concept did not resonate with smallholder farmers who access water for free and are more concerned with day-to-day challenges than conserving scarce resources and climate change. Seabex had to adjust their pitch and strategy for smallholders, highlighting the platform and pitching the IoT sensors as a complementary feature. The pitch now focuses on the cost advantages and productivity gains for farmers who use their platform.[148]

Telefónica Tech

In Latin America, Telefónica found that providing an automated irrigation system would be too big a step for farmers already wary of changing their irrigation and fertilisation practices, as was recommended based on data from the soil sensors. Farmers would be more willing to adopt the solution incrementally.[149]

147 GSMA. (2020). *Human-centred design in humanitarian settings: Methodologies and inclusivity.* Available at: https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2020/09/Research_Methodologies_R1_Spreads-1.pdf
148 Seabex interview (October 2021).
149 Telefónica interview (November 2021).

Recommendations for investors, donors and D4Ag providers in the smart farming ecosystem

RECOMMENDATION #3

Know the full cost of the solution and what users are both willing and able to pay.

The amount smallholder farmers are willing to pay for different smart farming solutions is directly related to the perceived economic benefit they would expect from implementing that solution. Several studies have shown, for example, that smallholders are willing to pay between $1 and $3 per collar per month for a smart livestock solution.[150] For a soil monitor that provides information on soil quality and generates recommendations for irrigation and fertiliser use, D4Ag providers have found that smallholders in Latin America are willing to pay $5 to $10 per month per sensor. For an automatic smart feeding system for use in aquaculture ponds, or a smart greenhouse that automates irrigation and pesticide application, smallholders may be willing to pay $1,000 to $2,000 in Indonesia. Seabex, for example, found that smallholder farmers in Tunisia would be willing to pay up to four per cent of their annual irrigation cost to upgrade to a smart irrigation system.[151]

Although there will be variations in pricing that reflect local market conditions, solutions that deviate too far from the above pricing may find it challenging to scale. D4Ag providers should have a solid understanding of the total cost of their solution (the cost of sensors, gateways, connectivity and ongoing support) and what their target audience is both willing and able to pay to reap the benefits of the solution. If there is a gap, D4Ag providers can target larger farmers until smallholders can afford it, or they may tap into government or third-party subsidies to help bridge the gap.

150 Quartz Africa. (2018), *Cattle theft in Kenya is being tackled with remote-tracking chip technology.* Available at: https://qz.com/africa/1197484/climate-change-kenya-cattle-theft-tackled-with-remote-tracking-chip-technology/.

151 Seabex interview (October 2021).

Recommendations for investors, donors and D4Ag providers in the smart farming ecosystem

RECOMMENDATION #4

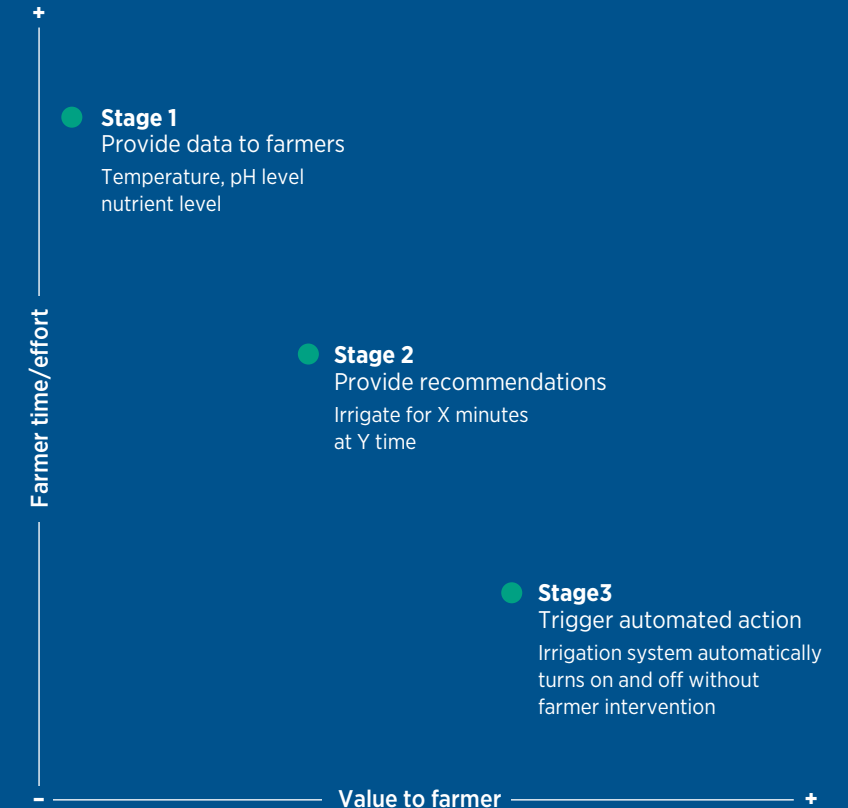## Focus on services that do more than just offer data.

Many of the early smart farming solutions were focused on providing detailed data to farmers. These data sets could include readings from soil sensors (with data on pH, moisture and nutrient levels), weather stations (temperature, precipitation, wind), aquaculture ponds (temperature and algae levels) and others. The solutions depended on farmers' understanding of the various parameters and their ability to translate the data into specific farm activities.

While this may work for large farms where there are trained agronomists onsite, it does not work in the context of smallholder farming where on-farm practices are often guided by years of tradition rather than data and science. Decision agriculture company Arable, for example, struggled to gain traction with their IoT-based solutions in Latin America because it was providing only the data, not the accompanying recommendations.[152] They therefore decided to make their APIs available to third-party D4Ag providers that could run the data from Arable's sensors through their own algorithms and provide smallholders with recommendations on specific actions they should take (e.g. when to irrigate/fertilise and how much water/fertiliser to use). In some cases, solutions can go beyond providing recommendations for automating actions (such as turning a water pump on and off, dispensing food to fish, etc.), making them even more productive.

152 Arable interview (July 2020).

Figure 59

Evolution of smart farming solutions

● **Stage 1**
Provide data to farmers
Temperature, pH level
nutrient level

● **Stage 2**
Provide recommendations
Irrigate for X minutes
at Y time

● **Stage3**
Trigger automated action
Irrigation system automatically
turns on and off without
farmer intervention

Farmer time/effort

Value to farmer

Source: Digital Agri Hub

Call to action

Digital Agri Hub publishes data on D4Ag solutions available in LMICs. We aim to provide a complete, global overview of digital deployments to inform investors, governments and other stakeholders.

If you are a D4Ag provider and your digital solution is not yet profiled on Digital Agri Hub's dashboard, or if your solution is already featured, but the data is not up-to-date, we want to hear from you. Please submit your data following the instructions.