FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

State of the Digital Agriculture Sector

Harnessing the Potential of Digital for Impact Across Agricultural Value Chains in Low- and Middle-Income Countries

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Table of Contents

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Foreword

Agricultural transformation sits high on the agenda for governments in many low-and-middle-income countries (LMICs) across the globe given the intertwining of the agriculture sector with critical national development outcomes – whether food security, poverty reduction, climate change adaptation and mitigation, or gender and social inclusion. With the right policy, investment, institutions, and innovation, agriculture and broader food systems can serve as powerful vehicles for inclusive economic growth, meaningful employment, and environmental sustainability across the world.

Digitalization is an increasingly central component to this transformation. It opens new portals to timely and locally relevant information, services, and markets across the agricultural supply chain, breaking down longstanding barriers to knowledge and resources linked to location and wealth. Digital solutions are bringing to bear new analytical, business, and relational models to help smallholder farmers and corporate agribusinesses alike get more out of their limited resources and generate value in new ways. Moreover, digital tools are creating new ways to understand and foster inclusion and resilience, creating new inroads into and means to engage with marginalized communities. Furthermore, digitalization in LMICs is itself being shepherded by a growing and increasingly diverse class of digital entrepreneurs–including a significant number that are youth–bringing a new wave of meaningful engagement with the agricultural sector.

DINA ESPOSITO
Assistant to the Administrator, USAID's Bureau for Resilience, Environment, and Food Security
Feed the Future Deputy Coordinator for Development
USAID Global Food Crisis Coordinator

While the digital for agriculture (D4Ag) sector has seen considerable and consistent growth over the past decade, in many ways and in many global markets, we are only beginning to see the promise and practice of D4Ag taking shape. Although the engine of technological progress is expected to power forward unabated, experience tells us that we should not take for granted its translation to inclusive and sustainable development. There is a critical opportunity at hand to take stock and learn from the current state and trajectories of D4Ag in LMICs–challenges, opportunities, achievements, and shortfalls alike– to help channel policy formulation, investment, and innovation itself in a positively-impactful direction.

The development of this 'State of the Sector' report was undertaken to do just that. USAID's Bureau for Resilience, Environment, and Food Security partnered with Beanstalk, the Bill & Melinda Gates Foundation (BMGF), the UK's Foreign Commonwealth & Development Office (FCDO), and DAI to produce the most extensive consultation on the state of D4Ag across LMICs to date. The report is an unprecedented attempt to consolidate a globally comparative perspective on the state of D4Ag ecosystems, including perspectives on level and dynamics of D4Ag adoption, proof of impact, and quantitatively- and qualitatively expressed alternative futures for the sector at large. Altogether, it lays out the case and roadmap for collaborative and complementary investment from stakeholders across the D4Ag ecosystem – innovators, policymakers, donors, investors, agribusinesses, and producers alike – to power the next wave of digitally-enabled sustainable development in agriculture across LMICs.

This report is not meant to be a static document but rather a call-to-action, inviting current and prospective partners to collaborate in fostering a robust and positively impactful digital agriculture ecosystem. We recognize that, as far as building a global evidence base, we are still at a starting point. I look forward to seeing this report's hypotheses and recommendations challenged and furthered by those that choose to take up the call to bring more rigor, evidence and impact to the sector. Its preliminary analysis indicates that with the right collaboration, investments, capacity building, and smart policymaking, the D4Ag sector's trajectory over the next decade could represent a minimum $500 billion value addition per year to the agriculture sector across LMICs. This "thriving" scenario would also likely close the gender gap by more than half, with 64 million additional women using D4Ag services. I hope that this report, and the efforts that stem from and are influenced by it, will help to guide investments and actions needed to secure and strengthen livelihoods, quality of life, and environmental sustainability across the globe through more commercially viable, inclusive, and climate-smart applications of digital technology in the agriculture sector.

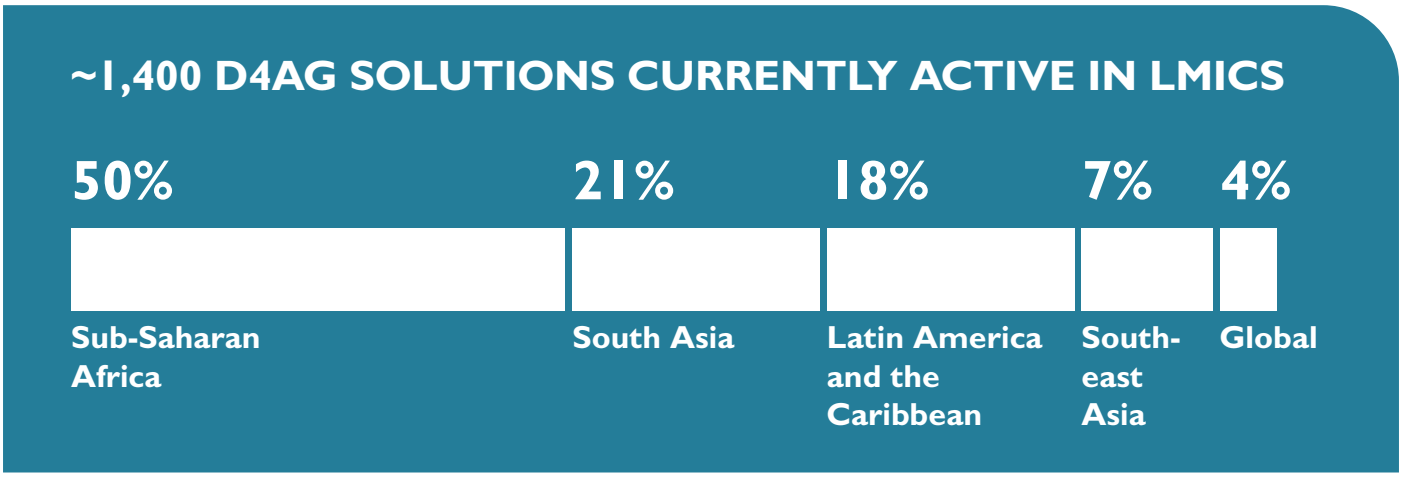
DINA ESPOSITO

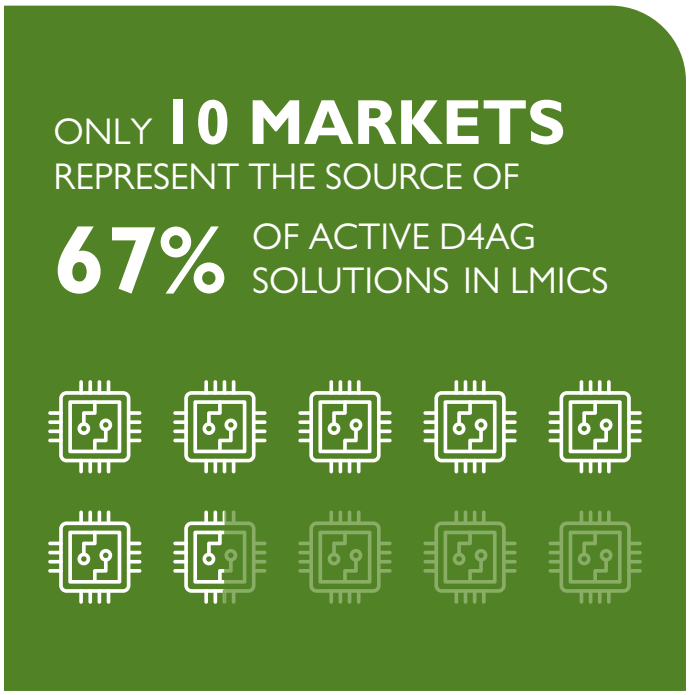
Assistant to the Administrator, USAID's Bureau for Resilience, Environment, and Food Security
Feed the Future Deputy Coordinator for Development
USAID Global Food Crisis Coordinator

Executive Summary

KEY FINDINGS

The past decade has witnessed an explosion in the global supply of digitalization for agriculture (D4Ag) innovation. Across the regions that comprise the focus of this report—Latin America and the Caribbean (LAC), South Asia (SA), Southeast Asia (SEA), and sub-Saharan Africa (SSA) (hereafter collectively referred to as "LMICs" (low- and middle-income countries))—we identified nearly **1,400 currently active D4Ag solutions**. These solutions represent six different D4Ag use cases: Advisory & Information, Market Linkages & Access, Financial Access, Supply Chain Management, Enterprise Management & Efficiency, and Enterprise R&D. The largest proportion is headquartered in **sub-Saharan Africa (50%)**, though a significant number of D4Ag solutions hail from **South Asia (21%)** and **Latin America and the Caribbean (18%)** regions. Despite showing the largest per-annum growth rate in the number of D4Ag solutions of any region over both the past five and ten years, respectively, **Southeast Asia** still accounts for a relatively small share of the total **(7%)**. The remainder (~4%) are active in but headquartered outside of the LMIC regions of focus (i.e., in North America, Europe, Northeast Asia, or the Middle East). Growth in the number of D4Ag solutions is decelerating. While **nearly half of all D4Ag solutions active in LMICs were started in the past five years**, there is a clear and consistent slowdown in the annual rate of new D4Ag solutions entering the market. The cumulative annual growth rate (CAGR) of the number of D4Ag solutions from **2012 to 2018 (33% p.a.)** was more than three times larger than that for the next four years, from **2018 to 2022 (9% p.a.)**. The trend of deceleration is common to every region, including relative upstart Southeast Asia. The deceleration certainly reflects a blend of increasing market maturity, consolidation, rationalization, and even COVID-19 impact—especially as sub-scale innovators start to close their doors and some venture-invested companies have shown themselves to be at the end of their ropes.





GEOGRAPHIC DISTRIBUTION OF D4AG SOLUTIONS

61%
in **Latin America & the Caribbean** are headquartered in **Brazil**

86%
in **South Asia** are headquartered in **India**.

45%
in **Sub-Saharan Africa** come from **Kenya** and **Nigeria**

49%
in **Southeast Asia** are headquartered in **Singapore** and **Indonesia**

D4Ag innovation is (slowly) decentralizing. Only **10 markets represent the source of 67% of active D4Ag solutions in LMICs.** While this is quite high, it is a slight decline from the 70% mark just five years ago, and the 75% mark of 2012. D4Ag solutions active in LMICs hail from an **astounding 81 countries at present,** up from 71 in 2018 and 42 in 2012. While each LMIC region reflects fundamentally different market structures within them, the existence of (typically) one regional D4Ag innovation "hub" is evident: **61%** of D4Ag solutions in Latin America and the Caribbean are headquartered in **Brazil**. **86%** of D4Ag solutions in South Asia are headquartered in **India**. **45%** of D4Ag solutions in sub-Saharan Africa come from **Kenya and Nigeria**—69% from those two plus Ghana, South Africa, and Tanzania. This decentralization, in D4Ag's most populous LMIC startup region, could portend a similar fanning out across other LMIC regions.

Source: Feed the Future Flickr. Photo credit: SM Tamzid Al Fatah

PRINCIPAL GROWTH CHALLENGES FLAGGED BY D4AG INNOVATORS DURING INTERVIEWS

58%
access to funding

38%
difficulties in user adoption

31%
lack of skilled talent

23%
lack of supporting infrastructure

19%
regulatory constraints

REACH & ADOPTION

Reach of D4Ag is continuing to soar, though a lot of headroom remains. Across LMICs, **we estimate that D4Ag solutions have amassed upward of ~50 million active users.** This amounts to about 10% of smallholder farming households in LMICs.[1] **Under the positive scenario, we expect this number to grow to 224 million farmers actively using D4Ag solutions by 2030, reaching a CAGR of 16%.** We need to clarify, however, that for the purposes of this report, when talking about the reach and adoption of D4Ag, we focus on specialized, purpose-built D4Ag solutions, excluding generalized technologies that might be used in agriculture but that are not specifically designed for it (like social media or mobile money platforms, which are sometimes included in other studies). We are also estimating the number of "active users", as opposed to simply the number of registrants, to allow us to consider the impact of these tools on farmers' economic and social lives. Please refer to Chapter 2 for further details.

More than half of current registrations come from South Asia—more specifically, India—where we have observed several D4Ag pioneers balloon to well above 15 million registrants and seen several others grow from scratch to >2.5 million registered users in the past five years. Still, with 160 million smallholder farmers in India, these are still the early days of sector growth.

Growth has been steady, especially at the "top", where the number of **D4Ag solutions with over one million registrants** grew from an estimated 11 to 27 from 2018 to 2022. While the supply of innovation remains somewhat concentrated, users across the continent are getting in on the action. Sub-Saharan African innovators were most "international" (per our count, active in an average of 1.6 countries per solution (mostly within the region), as compared to the next highest (1.3) in Latin America and the Caribbean); and the 10 D4Ag solutions in sub-Saharan Africa with the highest identified numbers of registered users in 2022 represent at least 15 different markets in the region. By number of registered users, Southeast Asia and Latin America and the Caribbean represent a relatively small share. Neither region, for example, could be shown to boast a solution with a registered user base of one million or

1 There are 500 million smallholder farming households in the world. Source: A Year in the Lives of Smallholder Farmers (worldbank.org)

more. In Southeast Asia, this reflects both the combination of relative industry nascency and the diversity and difference of cultural and socioeconomic landscapes across the region. In LAC, though, it is more likely explained by the general difference in solution mix and farmer demographics—a higher share of enterprise management and supply chain management solutions, targeting deployment on large-scale farms and/or through corporate agribusiness clients providing access to large swaths of farms in their supply chains. Among our interviewees (specifically D4Ag startup founders), the key challenge restricting the growth of their solutions was and remains **access to funding (58%)**. A notable **38%** struggle with **difficulties in user adoption**, while **31%** are restricted by **lack of skilled talent** in their regions. Poor supporting **infrastructure** and **regulatory constraints** in LMICs were also commonly referenced as key challenges (by **23%** and **19%** of innovators, respectively).

The extension of D4Ag tools to women, and other potentially disadvantaged sub-populations, remains limited. Recent years have seen substantial investment and knowledge generation with regard to gender & social inclusion in (digital) agriculture, particularly in the design of "inclusive" D4Ag solutions. It is not evident, however, that this is widely practiced in the D4Ag sector. By our estimate, **the average share of users who are female for any given D4Ag solution is 26%**. We are confident that this represents some level of progress in recent years. For sub-Saharan Africa specifically, for example, respondents to a survey of D4Ag innovators that we deployed suggested that ~36% of registered users were female, as compared to 25% reported by "The Digitalisation of African Agriculture Report 2018–2019" authored by CTA and Dalberg Advisors in 2019. But given the centrality of women in agricultural value chains across LMICs, there is certainly a great deal of headroom to be had. There were very few D4Ag solutions identified with an expressed focus on the inclusion of women or other potentially disadvantaged sub-populations. **While more than two-thirds of D4Ag innovators interviewed reported sex disaggregation of registration data, virtually none reported the use of such data for strategic or operational reasons** (e.g., to

ACTIVE USERSHIP OF SPECIALIZED, FOR-PURPOSE D4AG TOOLS

17%	Latin America & the Caribbean
10%	South Asia
6%	Southeast Asia
5%	Sub-Saharan Africa

Estimated percentage of farm enterprises

THE AVERAGE SHARE OF USERS WHO ARE FEMALE FOR ANY GIVEN D4AG SOLUTION IS

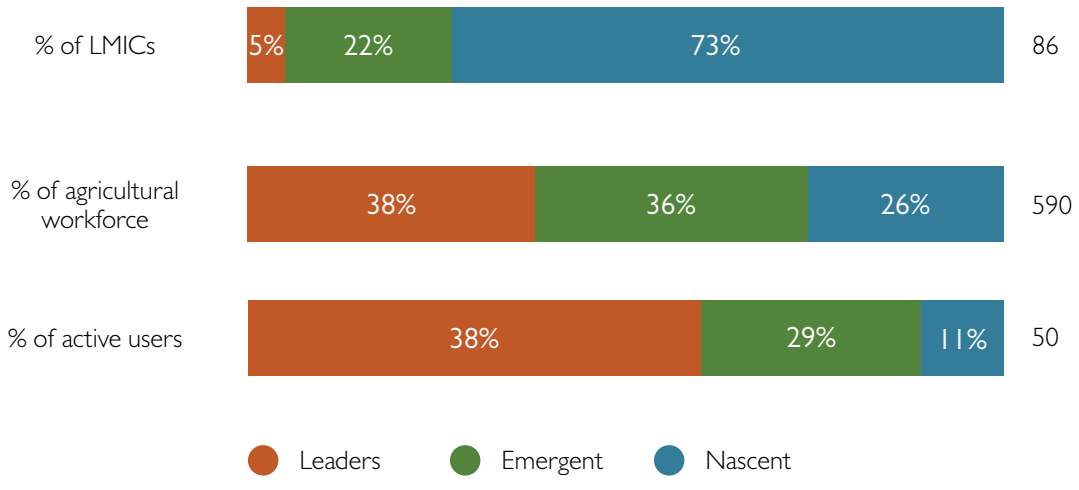
~40%

of D4Ag solutions are tackling at least two D4Ag use cases

tap into a commercial opportunity of uniquely underserved users). **Zero innovators whom we engaged or surveyed reported collecting registration data disaggregated across other (than sex and age) sociodemographic factors**. As such, the extension of D4Ag tools to other sub-populations (i.e., ability, indigeneity, sexual orientation, and minority status) remains unknown. What is known is that there are just about no commercial D4Ag solution providers (and certainly none at scale) that have centered social inclusion (beyond gender) within their organizational and business strategy.

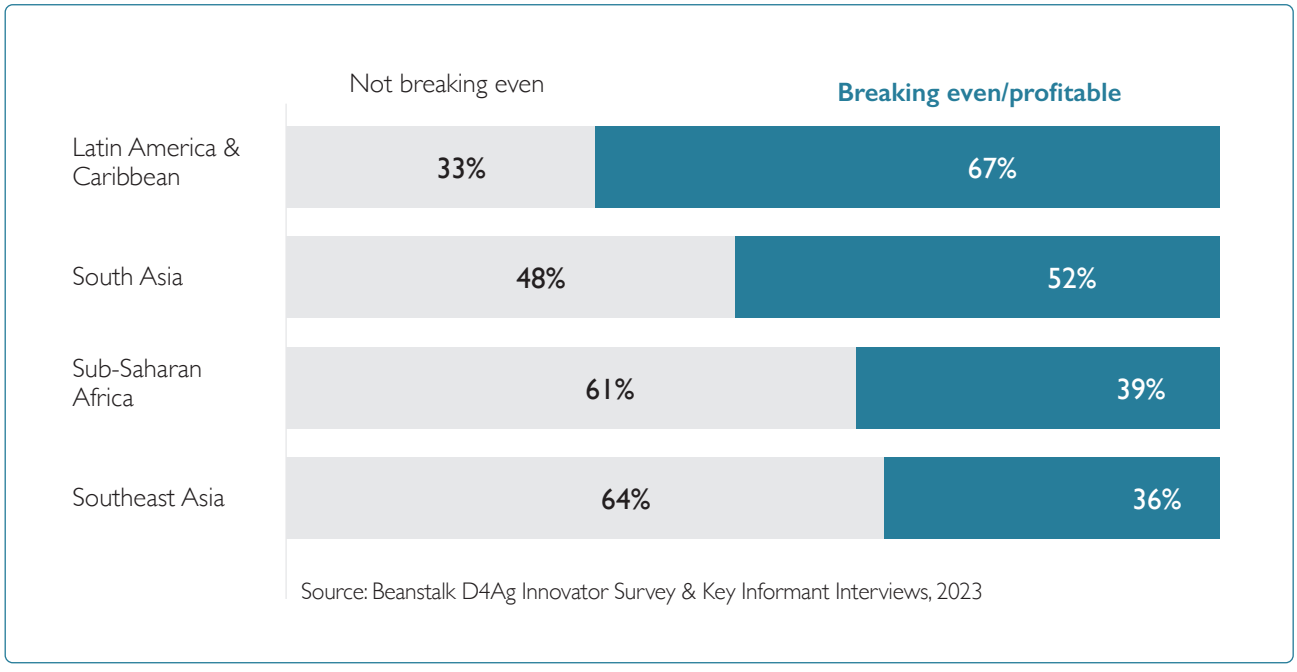
While the mix of use cases offered by solutions is relatively stable, both "divergence" and "convergence" are at play. As compared to 2018, the relative share of D4Ag solutions offering each of the six identified D4Ag use cases is relatively unchanged. The most notable shift is a decrease in D4Ag focused on **"Advisory & Information" (26% in 2018 to 22% in 2022)**, set against an almost equal increase in D4Ag focused on "Market Linkages & Access" (26% in 2018 to 30% in 2022). We believe this is meaningful and driven by factors including easier monetization, the post-COVID sustained demand and comfort with e-commerce and digital marketplace solutions, as well as a general challenge for D4Ag innovators to open new line items of cost (i.e., for standalone advisory services) apart from existing transactions. While the often-forecasted rise of "super platforms' has not yet been realized at scale in LMICs, there is a clear trend toward bundling, with **nearly 40% of D4Ag solutions tackling at least two D4Ag use cases**. New business models and revenue pathways (i.e., novel financial services and carbon marketplace solutions) are driving greater diversification of the offerings within respective use cases—we bucketed into more than 20 different use case sub-categories (see Glossary).

ESTIMATED SHARE OF AGRICULTURAL WORKFORCE AND ACTIVE D4AG USERS IN MARKETS OF NASCENT, EMERGING, AND LEADING D4AG ECOSYSTEMS (2023)



COMMERCIAL STABILITY

Commercial viability is improving, but quite unevenly. Our findings suggest that as much as **half of established** (excluding "pre-commercial") **D4Ag innovators** across LMICs **are operating at or above breakeven**. Clustering is quite regional: innovators in sub-Saharan Africa and Southeast Asia are—according to our survey—much more commonly unprofitable. Less than **40% of commercial innovators report operating at or above breakeven in those regions. The same numbers for South Asia and LAC are 52% and 67%**, respectively. There is a lack of baseline data to compare with on a global scale, but—both on the whole, and within regions—we are confident that this is a significant lift upward from recent years. A survey deployed for the development of CTA's 2019 report, for example, found that only 26% of their respondents were operating at or above breakeven—a jump to 39% in five years is significant. We were surprised, however, to find that the relationship between profitability and scale (of user base) was not significant. The proportion of profitable enterprises with 1,000 to 50,000 registered users (64%), for example, was far above the same proportion of enterprises with 50,001 to 500,000 and those with 500,001 to 1,000,000 registered users (35% and 50%, respectively). This indicates that unit economics is not just a function of scale: as these solutions expand from one geography to another, one crop to the next one, profitability often gets adversely impacted. At the same time, it is quite clear that different use cases have shown a more straightforward path to revenue generation and profitability than others.



Profitability of Surveyed D4Ag Innovators, Per Region
(% of innovators surveyed (n=75))

FUNDING & INVESTMENT

Funding and investment for D4Ag, while not systematically tracked, have clearly seen a massive upswing in recent years. Cumulatively through 2021, **LMIC regions had seen the deployment of ~US$13.2 billion in funding and investment for AgTech** more broadly (approximately one-third of the global total). About **US$5.8 billion (44%) of this total has come from (sub-)commercial investors**, including venture capital and private equity. Lesser shares have come from other categories of funding, including private foundations, development finance institutions (DFIs), and multi/bilateral investment vehicles. Africa's (sub-)commercial investment market, which has supplied merely 12% of the region's US$5.4 billion AgTech investment to date, is uniquely shallow across LMIC regions (LAC was the next lowest, at 47% of regional investment from (sub-)commercial investment). The vast majority (by number of investments) remains in pre-seed to Series A investments, with India as a standout for the prevalence of later-stage investments in mature D4Ag startups. What is clear is that the bulk of funding and investment for D4Ag has continued to be directed toward specific innovators rather than cross-sector investments (i.e., in data and digital infrastructure (apart from mobile and internet connectivity)). More specifically, the lion's share of investment has been directed toward "Market Linkages" and "Financial Access" solutions (>US$1 billion in 2021), where there are clear models for monetization, familiar pathways to scale, and an understanding and acceptance of large capital requirements to "win." With everything above accounted for, bootstrapping is still the most common funding pathway for D4Ag innovators: the **vast majority (77%) of active D4Ag innovators in LMICs have not raised external funds**.

LMIC REGIONS HAVE SEEN THE DEPLOYMENT OF

~$13.2 BILLION
IN FUNDING & INVESTMENT
FOR AGTECH

About **$5.8 BILLION (44%)** of this total has come from
(SUB-)COMMERCIAL INVESTORS

Source: Feed the Future Flickr. Photo credit: Imran Abdullahi

IMPACT

We are getting a clearer picture of the impact of D4Ag, but there is still more "noise" than "signal." Theoretical impact pathways point to the potentially transformative role of D4Ag in economic, environmental, and social outcomes for farmers and stakeholders across agricultural value chains. To date, the "evidence" remains mostly anecdotal and housed in innovators' marketing collateral. Professional and academic impact studies have generally been limited to "economic" aspects of impact and have been centered on validating positive rather than potential negative impacts from D4Ag deployment. Still, we are gaining a better understanding over time as to how, and under what conditions, different D4Ag solutions are generating positive impact.

Productivity (strong evidence): While the magnitude is difficult to pin down (independent studies have shown a range of **0–170% yield improvement**, with little clustering in between), the contribution of D4Ag to improved productivity—through, for example, improved weather forecasting, fertilizer application recommendations, or simply making possible the purchase of enhanced inputs—has been corroborated across LMICs in various geographical and value chain contexts. What is also clear is that access to information, whether prices or new production practices, is typically insufficient to enable practice change. The greatest returns have been observed in the deployment of combined "Advisory & Information" services with "Market Linkages" or "Financial Access"—which unlock liquidity and means of practice change for producers—and are cognizant of the "physical" realities of producers' locales (i.e., known availability of recommended inputs). Much less explored is the impact of D4Ag on the productivity of agribusinesses across the supply chain (i.e., cost savings from improved demand forecasting).

Income (strong evidence): Income effects of D4Ag have been observed with regularity over the past decade (typically from **2% to 20%, but with some positive outliers citing up to 60% income improvement on- and off-farm**). Beyond the economic impact of productivity, there are several other pathways through which D4Ag has shown promise in advancement of net income within and across the agricultural supply chain. Most tangibly and commonly, this effect has been on cost savings—i.e., procuring quality inputs at cheaper prices; or applying labor, chemicals, fuel, and fertilizer more efficiently. Additionally, dating back to the first deployments of "Market Linkages" solutions and mobile phones more broadly, farmers continue to demonstrate clear benefits from improved price realization—leveraging digital tools to better time marketing, and investing in highest-return marketing partnerships. A new class of emerging D4Ag solutions are enabling an additional income effect through new revenue streams, as exemplified through digital measurement, reporting, and verification (d-MRV) tools unlocking access to carbon markets, and entrepreneurial opportunities afforded through equipment-leasing tools. While most nascent among income improvement pathways for D4Ag, these solutions present potentially the most transformational economic impact pathway dependent specifically on the advent of digital tools, opening new pathways for even smallholder farmers to generate return on assets apart from commodity production. It is important to recognize, however, that "physical" assets—infrastructure, quality inputs, trusted expertise, marketing and logistics partners, fit-for-purpose equipment and machinery, etc.—are crucial ingredients to unlock the value of digital in each of these income improvement pathways, and often represent the "weak link"

IMPACT OF D4AG OBSERVED TO DATE

Productivity
independent studies have shown **0-170% yield improvement**

Income
typically from 2-20%, but with some positive outliers citing up to 60% income improvement on- and off-farm

Gender Equity
Growing body of evidence supporting claims of positive impact on women from D4Ag

Social Inclusion
Public and development agency research at the intersection of digital agriculture and broader social inclusion seems relatively nascent.

Environmental Sustainability
D4Ag will unlock further opportunities for climate change adaptation and resilience.

in the chain. As with productivity, less explored and validated to date have been the impacts of D4Ag on costs and returns for agribusinesses, agriculture adjacent businesses (i.e., financial services providers and mobile network operators), and governments. For example, digital tools' impact on the cost efficiency of customer acquisition and support activities, rural loan book value and (non-)performance, and government benefits provisioning—all of which indirectly benefit smallholder farmers—has not generally been in the spotlight.

Gender Equity (some evidence): In general, it is clear that the sector is not collecting enough information on gender-specific and gender-disaggregated usage and outcomes from D4Ag to make systematic claims on the impact of D4Ag on gender equity in LMICs. There is, however, a growing body of evidence supporting claims of positive impact on women from D4Ag, particularly with respect to women's economic empowerment. Digital tools have shown the capacity to support women to improve productivity and income through improved access to knowledge, resources, and financing, as well as develop wage-enhancing professional qualifications. The boundaries and limitations of D4Ag's positive impact on gender equity, as well as potential negative impacts of D4Ag on gender equity, have been anecdotally and quite commonly reported, but less observed. This is likely due to both sensitivity and the challenging nature of this kind of targeted research—for example, due to the purported "invisibility" many women users of D4Ag—as well as a general lack of looking for the "negatives" of D4Ag by self-interested

parties. We know that social norms, resource inequities, and intrahousehold responsibilities can limit or outright counter positive impacts from D4Ag. While there are anecdotal stories of such being circumvented, this comes with social consequences and risks, which should be acknowledged and considered for locale- and cultural-specific contexts. Much less explored have been the implications of the D4Ag ecosystem's development on gender equity across agricultural value chains, and vice versa (i.e., how D4Ag sector growth is contributing to education and employment for women and girls in STEM, or alternately how increasing gender equity in LMIC investment ecosystems influences funding for innovators tackling GESI-specific challenges).

Social Inclusion (low-to-no evidence): As touched on previously, there is very little disaggregation of data on registration—let alone usage and outcomes—for sociodemographic segments outside of "gender" (and to some extent, "age"). This includes people living with disabilities, indigenous peoples, ethnic minorities, culturally and linguistically diverse populations, individuals of various sexual orientations, and various further globally and locally relevant social strata. Public and development agency research and programming at the intersection of digital agriculture and broader social inclusion for these sub-populations seem relatively nascent. Thus—beyond sparse evidence of individuals' broadening their professional networks through D4Ag—what we have learned about the potential for D4Ag to support broader social inclusion is largely theoretical and anecdotal. Theories and anecdotes do, though, hold promise—whether in the case of digitizing otherwise inexpressible land titles (see **Papyrus** in Haiti), providing tools for intermediaries to better support people living with disabilities to advance agricultural enterprise (see **RehApp**), or extending digital advice and information through interactive voice response (IVR) and video rather than text for those with low literacy and/or language skills. A closer review of experiences and outcomes for specific sub-populations will help to clarify the real potential of D4Ag to improve broader social inclusion.

Photo credit: M-Shamba

Environmental Sustainability (low-to-no evidence): As discussed previously, agriculture and climate change are fatefully intertwined. Agriculture, in virtually all countries and production systems, is one of the world's top two to three greenhouse gas (GHG) emitting industries. At the same time, (smallholder) farmers are uniquely vulnerable to the effects of climate change. For many, AgTech (of which D4Ag is a subset) has become synonymous—or at least, a subdivision of—ClimateTech. The deployment of technology solutions and broader practice change have long been identified as critical to the fight against climate

change, and to adaptation through it. First, this comes through the potential for climate change mitigation—i.e., d-MRV's enablement of carbon offset projects in LMICs, variable rate fertilizer prescriptions reducing nitrous oxide emissions through degasification of overapplied nitrogen fertilizer, or feed optimization tools improving the methane intensity of bovine meat production. Physical inputs—such as biological replacements to synthetic fertilizers, methanogenesis-limiting feed additives for ruminants, and labor-saving technologies for alternate wetting and drying of rice paddies—could have equal or more significant effects and will likely be critical complements to digital innovation. D4Ag will also unlock further opportunities for climate change adaptation and resilience—i.e., AgFinTech tools enhancing access to credit for water-harvesting infrastructure on-farm, digital microbial libraries and discovery platforms supporting the development of drought-resistant crop varieties, or weather forecast apps advising farmers to take rapid action to prepare fields ahead of extreme weather events. However, the impact of D4Ag on climate change mitigation, adaptation, and resilience in practice has yet to be systematically assessed. In fact, there is good reason to believe that in many cases the opposite could be true (i.e., more nitrous oxide emissions due to increased access to and use of synthetic fertilizers).

ECOSYSTEM FOUNDATIONS

Across LMIC regions, "Foundations" of the D4Ag ecosystem have undergone substantial transformation in the past five years, though there is room yet to grow.

Policy and Regulation: Policy maturity related to D4Ag varies across LMICs, and a consistent trend reveals a fragmentation and oversight of the sector in overall digital transformation policies. We identified only **23 LMICs with policies specific to digital agriculture, 10 of which are in sub-Saharan Africa**. This has often resulted in D4Ag falling between the cracks or being micromanaged by multiple entities without clear prioritization.

The direct involvement of governments in D4Ag has produced mixed results, sometimes fostering the development of productive and

Source: Feed the Future Flickr. Photo credit: Guilherme Castro, Cromai

Policy and Regulation:

23 LMICs

with policies specific to digital agriculture, 10 of which are in sub-Saharan Africa

People and Skills:

31% of innovators

we surveyed called this out as a principal concern

inclusive innovation ecosystems, and at other times directly competing with and crowding out private innovators. For example, government-sponsored platforms often offer similar services at a subsidized cost or for free, making it difficult for private enterprises to compete. Furthermore, when/if these government-led initiatives fail, they tend to undermine trust in similar private-sector services. Further, policy misalignment across levels of governance is quite common across LMICs, often leading to diluted strategies and constrained support for D4Ag ecosystems.

People and Skills: Despite the obvious potential, D4Ag ecosystems globally are **struggling to attract and retain skilled staff. As much as 31% of innovators we surveyed called this out as a principal concern** (up to 44% in sub-Saharan Africa), particularly with respect to software development, data science, and business development. The movement of talent from rural to urban areas and/or to international tech hubs—the "double brain drain"—further exacerbates this issue. However, countries are implementing creative strategies to counter the talent drain, such as locally targeted tech hubs, incentives for returning professionals, and leveraging the diaspora strategically for expertise and capital.

Universities, when empowered, can become transformative forces in D4Ag ecosystems, as seen in India. Educational institutions also play a significant role in promoting gender & social inclusion within the D4Ag sphere by creating opportunities for underrepresented groups, contributing to ecosystem dynamism and inclusivity. However, many face challenges due to a fragmented inclusion of digital skills in agricultural curricula and a lack of collaboration between universities.

D4Ag innovators often compete with sectors perceived as more attractive (e.g., FinTech, HealthTech, EdTech) for specific skills, compounded by the perception of agriculture as "slow" and backward-looking. Regionally, this situation varies, with examples like Latin America, where recruitment of agricultural talents is challenging due to competition from established agribusiness corporations.

Knowledge and Capabilities: The level of digital literacy varies widely across LMICs and often acts as a significant barrier to the effective adoption of D4Ag tools. The challenge is not just about understanding the basics of the internet and devices use, but also about grasping the diverse requirements that different D4Ag solutions might demand. For instance, some tools might function optimally on specific mobile data networks or require regular updates and synchronization. A lack of familiarity or comfort with these requirements can hinder

users from maximizing the benefits of these tools, or even from using them at all.
In response to literacy challenges, innovators are exploring methods to make D4Ag tools more accessible and enjoyable, such as the "gamification" of tools. Simultaneously, hybrid models combining physical and digital delivery channels are emerging as a solution to enable participation in digital systems without requiring extensive individual digital literacy.

Contrasting experiences in places like India, where digital literacy among target users is often underestimated, indicate the necessity for a more nuanced understanding of digital literacy levels across different contexts. It underlines the need to tailor D4Ag solutions to the abilities and expectations of target users.

In markets and regions where basic literacy still poses a significant barrier to digital adoption, alternative delivery channels such as video delivery or IVR have been used extensively. Far from 'silver bullet' solutions, though, these come with their own limitations.

Networks and Social Capital: Social media and messaging platforms like WhatsApp, Facebook, and YouTube have become essential for networking, market intelligence, and knowledge sharing within the D4Ag communities across LMICs. They serve as platforms where farmers share experiences, ask questions, and receive advice, enhancing agricultural productivity. We have identified, for example, four different YouTube channels dedicated to agricultural knowledge dissemination in India alone with more than one million subscribers, and 10 similarly focused LMIC-based Facebook groups with more than 100,000 members.

On the other hand, the means of network-building and knowledge dissemination continue to multiply. Newsletters, podcasts, blogs, and similar content delivery platforms have fostered new virtual spaces for knowledge sharing, enhancing industry understanding, and exposing users to innovative practices in D4Ag. Non-textual platforms like TikTok have also shown effectiveness in engaging audiences and disseminating information.

Source: Feed the Future Flickr. Photo credit: Maria Luisa Ramirez Cruz

Research and Development (R&D) Funding for Sustainable Agriculture

US$10.5 billion
annual funding gap

Access to Credit for Farmers

~1.4 billion adults
still unbanked as of 2021, globally

Funding and Investment: Funding remains critical for the growth and sustainability of D4Ag ecosystems. This includes funding not only for individual innovators, but also for the advancement of a nurturing, robust D4Ag ecosystem.

Funding for Individual Innovators: Innovators developing D4Ag solutions often face resource constraints. Adequate capital is required to support research, development, product market readiness, scaling operations, enhancing innovation, capacity building, and risk mitigation. From our interviews and research, we were consistently pointed to common and persistent gaps in commercial investment landscapes crucial for LMIC-based innovators (i.e., in sub-Saharan Africa, the "missing middle" between small-scale grants below US$50,000 and typical threshold ticket size for venture capitalists (VCs) at US$750,000) and working capital (i.e., overdraft facilities and short-term debt). Overall, access to funding was the most referenced barrier faced by D4Ag innovators in LMICs, with almost 60% of solution providers admitting to facing such difficulties. There is also a clear lack of visibility on early-stage D4Ag startups, specifically grant-funded and unfunded solutions, in LMICs. This can largely be attributed to the fact that many existing databases often fail to capture data on early-stage solutions in these markets: For example, three leading investment databases (Pitchbook, Tracxn, and Crunchbase) each contained only 30%–40% of the >1,300 solutions that sit in our database. This lack of visibility in the market constrains investors' pipeline building, due diligence process, and ability to identify co-investors, ultimately lengthening transaction timelines or dissuading investors from entering new markets, thereby contributing to persistent funding gaps.

Infrastructure Funding: D4Ag relies heavily on technology-driven infrastructure, such as physical and digital networks, data centers, and hardware. Investment in infrastructure is vital for successful deployment and scalability of digital agricultural tools and platforms. However, infrastructure often receives disproportionately low attention from the public sector.

Research and Development (R&D) Funding: R&D funding fuels scientific and technological advancements for agricultural innovations. Despite the growth in agricultural public sector support, it often fails to meet its aims of improving food security, livelihoods, and environmental sustainability. **An investment gap exists in R&D for sustainable agriculture intensification in LMICs, currently standing at US$10.5 billion annually.**

Source: Feed the Future Flickr. Photo credit: Rakotonantoandro Lalaina

Access to Credit for Farmers: Financial access is crucial in the D4Ag funding ecosystem. Farmers often rely on credit to acquire necessary agricultural inputs, but may resort to borrowing from informal sources with high interest rates and unfavorable terms. Despite an increase in credit to agriculture, its growth has been slower than in other sectors. Furthermore, significant gaps in financial inclusion remain, with **around 1.4 billion adults still unbanked as of 2021, globally.**

Data and Infrastructure: The role of data and infrastructure in D4Ag has grown significantly, with substantial investments leading to noticeable improvements in the availability of public sources of weather, soil, productivity, and market information. The effectiveness of D4Ag solutions is highly dependent on the quality, accessibility, reliability, sustainability, and relevance of these infrastructures. A strong D4Ag infrastructure in LMICs should be robust, able to withstand various challenges and handle large data volumes from multiple sources. It should be accessible to all stakeholders and reliable in providing accurate and timely information. The infrastructure should also be sustainable, both environmentally and economically, and remain relevant by delivering data and insights that directly support the needs of its users.

Despite increased data availability, factors like accessibility, comprehensibility, granularity, and data integrity limit the contribution to the D4Ag ecosystem: **23% of surveyed innovators said that a lack of supporting infrastructure prevents them from scaling their solutions.** A few countries, like India, have made notable efforts to invest in more sophisticated agricultural data warehousing and analytics infrastructure. In the spotlight—for challenges, opportunities, and complexity at present—are "data sharing" and "data governance."

Sophisticated software capabilities are becoming more accessible in D4Ag, with machine learning (ML), blockchain, artificial intelligence (AI), systems integration, and customer relationship management (CRM) leading the way. However, these technologies also present issues related to cost, complexity, rural connectivity, digital literacy, and data privacy and security. For example, transparency and interpretability of AI-driven decision-making have raised ethical questions. Hardware requirements and associated costs are key considerations, often impacting uptake and business models in D4Ag. Some promising models, like hardware as a service (HaaS), have emerged, offering skills-building and entrepreneurship opportunities.

Internet connectivity, data affordability, and device ownership remain significant barriers to D4Ag adoption among smallholder farmers in LMICs. Despite some improvements, internet and mobile penetration, as well as data rates, continue to be challenges, particularly for those with low or unstable income. **While the smartphone adoption rate in emerging markets has grown to ~40%,[2] only about one-third of farms less than 1 hectare in size are served by 3G or 4G services.**

Data and Infrastructure

23% of innovators
said that a lack of supporting infrastructure prevents them from scaling their solution

only 1/3 of farms less than 1 hectare
are served by 3G or 4G services.

2 Accelerating Affordable Smartphone Ownership in Emerging Markets, GSMA, 2017
Mehrabi, Z.; McDowell, M.J.; Ricciardi, V.; Levers, C.; Martinez, J.D.; Mehrabi, N.; Wittman, H.; Ramankutty, N.; Jarvis, A. (2020) The global divide in data-driven farming. Nature Sustainability, Online first paper (02 November 2020) ISSN: 2398-9629

CHALLENGES, CONSOLIDATED

Consolidated from and reflecting on the assessment of LMIC-based D4Ag ecosystems across the globe, seven core challenges stood out as most constraining the emergence and sustainability of an inclusive, climate-smart, and commercially viable D4Ag sector:

Disconnected knowledge sharing and collaboration networks:

Traditional agricultural insights are often overlooked, causing disconnects and missed opportunities in D4Ag initiatives. Duplication in donors' D4Ag programs leads to inefficiencies and reduced potential for learning. Siloed government operations obstruct the sharing of best practices across regions, further hindering progress.

Uncertainty of financial viability:

Concentration of funding neglects certain sectors, and a lack of successful exits diminishes growth prospects. Underserved financing areas hinder small-scale innovators, while donor-driven market distortions risk long-term sustainability. A lack of visibility and data on early-stage D4Ag solutions in LMICs contributes to persistent funding gaps.

Poor accessibility and quality of physical and digital infrastructure:

Public data issues, duplication, and lack of sharing incentives can lead to misinformed decisions. A disproportionate focus on crops over livestock and aquaculture misses potential opportunities. Infrastructure challenges, including gaps in middleware and hardware constraints, limit D4Ag's reach and efficacy.

Shortcomings in user engagement and market penetration:

Digital fatigue and a lack of physical support diminish user engagement. Misunderstandings of target markets due to lack of diverse input lead to solutions misaligned with users' true needs. Moreover, a common feeling of distrust towards top-down developed technologies among farmers and reservations about sharing personal and farm data further hamper the adoption.

Constraints on climate-smart D4Ag deployment and credibility:

Limited localized climate data constrains effective adaptation and mitigation strategies. The neglect of public data assets and absence of government frameworks impede aligned climate-focused efforts. The risk of "greenwashing" threatens market integrity and trust in sustainable initiatives.

Persistence of gender inequality and social exclusion:

Barriers like access and cultural norms limit penetration among marginalized groups. The absence of strong incentives and skewed representation results in biased or misaligned solutions. A lack of standardized gender & social inclusion indicators complicates measuring and promoting inclusivity.

Lack of quality impact measurement:

Unattended adverse impacts risk causing unintended harm. An existing evidence gap combined with challenges in quality measurement and lack of data transparency at a market-level obstructs a clear understanding of D4Ag's true impact.

FUTURE OUTLOOKS

A few forward-looking trends—some bolder than others—stand out in particular as highly likely to bear fruit given historical trends, expert perspectives, committed investments and policies, and market cyclicality.

Ecosystem Foundation Development: From an infrastructural perspective—drawing on current trends and planned investment—we are expecting significant growth in smartphone and 3G+ connectivity in the coming decade, enabling much broader access to D4Ag among remote and diverse farming segments. For example, it is expected that by 2030, mobile internet penetration will reach 64% globally (up from today's 55%). Device ownership gaps are expected to narrow, with smartphone adoption in regions like sub-Saharan Africa reaching 87%. From the regulatory perspective, we expect a new wave of regulations and policies drawing and building on pioneering governments in respective regions. These regulations are likely to not only provide greater clarity, confidence, and room to operate for D4Ag innovators and ecosystem partners, but also serve as foundational elements for the mainstreaming of GESI principles and climate change management strategies. We also expect broader "integration" of D4Ag with ClimateTech / climate change management—both in perception and in practice, signifying the strategic alignment of agricultural innovation with broader global agendas, particularly ensuring that development is inclusive and responsive to the planet's changing climate.

Macro Market Dynamics: Despite the aforementioned deceleration in D4Ag solution growth in recent years, we are expecting a "re-acceleration" in the number of D4Ag startups driven primarily through geographic diversification—"emerging" D4Ag ecosystems earlier in the D4Ag innovation S-curve. We expect that re-acceleration and expansion to newly maturing D4Ag markets will facilitate additional "boom" and "bust" cycles—more meteoric rises and falls that will reverberate through the sector. Hopefully, these will be moderated with success stories and learnings from the past decade so that shaken confidence can be avoided. Moreover, we anticipate a further "split" and divergence in trajectories, and perhaps ecosystems, between enterprise- and farmer-facing D4Ag—reflected in different

FORWARD-LOOKING TRENDS FOR WHICH WE HOLD A HIGH DEGREE OF CONFIDENCE

- Smartphone Accessibility
- Regulatory Evolution
- Climate Change Integration
- Divergent Trajectories
- Volatile Market Dynamics
- Expansion in Emerging Markets
- Continued Relevance of 'Point Solutions'
- Business Model Innovation
- 'Digitally Native' Agribusinesses

investor bases, growth cycles, and commercial viability. As use cases, business models, and ecosystems diversify, it will be increasingly important that D4Ag strategies and perspectives avoid being overly monolithic.

Business Model Evolution: While technological innovation is certain to remain both unflinching and important, business model innovation is likely to be more critical to the next wave of opportunity for D4Ag—unlocking new revenue streams, financial products, and intermediary models for the sector. With greater technological precision and business model diversification, we envision that—despite a general trend toward D4Ag platforms and bundles—there remains plenty of opportunity for "point solutions" targeting previously unaddressed challenges (especially deployed in conjunction with "physical" tools). Lastly, we anticipate the emergence of "digitally native" corporate agribusinesses. Much attention has been paid to prospects for and market developments indicating agribusiness majors (i.e., Bayer, Corteva, Syngenta, Yara, UPL, etc.) going "digital," but much less on D4Ag pioneers going "physical." We predict that we will start to see at-scale challengers to traditional agribusiness majors from D4Ag innovators who may more deftly leverage a "phygital" approach and lean less on (while competing with) legacy agri-product sales (i.e., leaning instead on bio-based alternatives, higher-margin services, etc.).

In addition to these "likely" predictions, we have framed a pair of "alternative futures," which we believe represent and model the lower and upper bounds for the growth, reach, and impact of D4Ag across LMICs in the next decade—what we call "derailing" and "thriving" scenarios. The aim is not precision, but a reflection of the magnitude of difference in getting the future "right" versus "wrong" for D4Ag sector development. The two scenarios reflect potential D4Ag-influenced futures drawn out across lines of smallholder livelihoods ("down and out" or "up and in"), innovation ("stifled" or "distributed"), environment ("degradation" or "regeneration"), culture ("erasure" or "enrichment"), inclusion ("systematic barriers" or "equitable access and benefit"), and digital foundations ("exploitation" or "shared stake and benefit")—as well as what such divergent outcomes could suggest for individual stakeholders.

In 10 years' time, we estimate that under the achievement of the "thriving" scenario, ~US$500 billion of value enabled by D4Ag is added to the agriculture industry every year across LMICs, representing an increase of 28% in value of total agricultural output across focus regions. In the "derailing" scenario, the majority (90%) of potential value, equivalent to US$450 billion, is eroded away by low uptake, low supply, and efficacy of solutions. Successful adoption of D4Ag solutions is the critical success factor—we see farmers accelerating adoption four times faster when the ecosystem is "thriving" versus "derailing," **reaching an average adoption rate of 38% across the LMICs by 2033, encompassing a vast population of 224 million users** who will have integrated D4Ag tools into their daily agricultural practices. From a gender inclusion perspective, **we estimate the gender gap to close by more than half, bringing 64 million more females into the D4Ag user ecosystem.** Lastly, there is huge potential for D4Ag to reduce farm-gate GHG emissions by 9% (-360 MMT CO2eq). D4Ag can create greater efficiencies, thereby enabling a lower climate footprint; however, farmers may also then choose to invest more into resources such as fertilizer inputs and fuel-based farm machinery, causing a worsening effect on GHG emissions (+140 MMT CO2eq per annum).

TWO SCENARIOS PAINT THE RANGE OF ALTERNATIVE FUTURES WE BELIEVE ARE POSSIBLE FOR D4AG IN LMICS - A $450B+ P.A. QUESTION

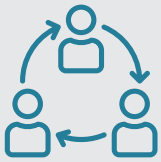
Under the 'thriving' scenario, ~US$500 billion of value enabled by D4Ag is added to the agriculture industry annually across LMICs, an increase of 28% in value of agricultural output across focus regions.

Innovation is **distributed**

D4Ag will reach an average **adoption rate of 38%** across LMICs, covering **224 million users**

Environmental **regeneration**

Farm-gate **GHG emissions** will fall by **9%**



Equitable access and benefit for all

The gender gap will close by more than half, bringing **64 million more females** into the D4Ag user ecosystem

Shared stakes and mutual benefit

Under the 'derailing' scenario, 90% of this potential value – US$450 billion – will be eroded by low uptake, low supply, and efficacy of solutions.

Innovation is **stifled**

D4Ag will reach an **adoption rate of ~10%** across LMICs

Environmental **degradation**

Systematic barriers to gender & social inclusion

Expectation of **exploitation**

RECOMMENDATIONS

With a focus on orienting the LMIC D4Ag ecosystems toward the "thriving" scenario, we have formulated a series of strategic recommendations (accompanied by illustrative and referenceable actions) for stakeholders across the D4Ag ecosystem:

1

Support the formulation and implementation of inclusive, climate-smart policies for D4Ag

Focus on creating robust policy frameworks that promote climate-smart digital agriculture, taking into account industry standards, regional alignment, and infrastructure development.

2

Invest in capacity building & knowledge sharing across the D4Ag ecosystem

Emphasize training for a digitally native agricultural workforce, close knowledge gaps on D4Ag's impact across diverse sectors, and promote digital literacy and empowerment especially among marginalized groups.

3

Sustain, boost, and diversify funding and investment for D4Ag

Drive more adaptive and outcome-oriented funding structures, identify and address principal funding gaps, and ensure investors incorporate impact into core investment processes and structures.

4

Accelerate the development of infrastructure to support D4Ag

Expand funding pathways for essential infrastructure, whether physical (i.e., rural telecommunication, warehousing, cold storage, and environmental monitoring technologies) or digital (i.e., data warehousing, farmer/land registries, environmental and demographic data layers, etc.).

5

Foster collaboration and data & resource sharing across the D4Ag ecosystem

Encourage multi-stakeholder engagements, comprehensive and accessible data on D4Ag innovations in LMICs data-sharing platforms, and strategic partnerships—both within and across the regions—to collectively address common challenges and visions for D4Ag and boost funding to the sector.

6

Hone in on D4Ag end-user needs through focused and inclusive engagement

Support and encourage innovators to differentiate with clear value propositions, embed inclusivity, and prioritize deep user engagement. Support and encourage primary producers to experiment, feedback, and advocate for capacity building.

Introduction

It is November 2023. A Guatemalan packhouse pulsates with the hum of machinery as hyperspectral sensors gauge the dry matter in a batch of avocados. On India's coast, a shrimp farmer scrolls through her smartphone, checking pond water quality and comparing market prices. Across the Indian Ocean in Kenya, a herdsman consults a digital directory of veterinary experts, seeking advice on a mysterious ailment sweeping his goat herd. Welcome to the era of Digitalization for Agriculture (D4Ag), transforming lives in low- and middle-income countries (LMICs).

Yet, as these individual threads of progress weave an optimistic tapestry, the broader landscape of agriculture in LMICs faces existential threats. Climate change introduces unprecedented volatility, while wide resource and gender gaps amplify the "digital divide." Political, fiscal, and public health upheavals—notably the aftermath of the COVID-19 pandemic—have further destabilized the sector. Rising fuel and input prices, catalyzed by conflicts such as the war in Ukraine, gnaw at the farmers' thin profit margins. Alarming reversals in the state of food insecurity and hunger, primarily driven by the pandemic and conflict, underline the urgency of transformation.

In this landscape, D4Ag emerges as a potent tool—a beacon that can guide the sector out of the storm toward more sustainable and equitable horizons. Harnessing advancements in AI, internet of things (IoT), and mobile technology, D4Ag has the potential to bridge resource gaps, democratize access to agricultural services, and render farming more resilient to climate volatility. However, this future is not preordained. If poorly managed, digital solutions could widen the digital divide and exacerbate inequities, replacing old challenges with new ones.

Source: Feed the Future Flickr. Photo credit: Rafi Respati

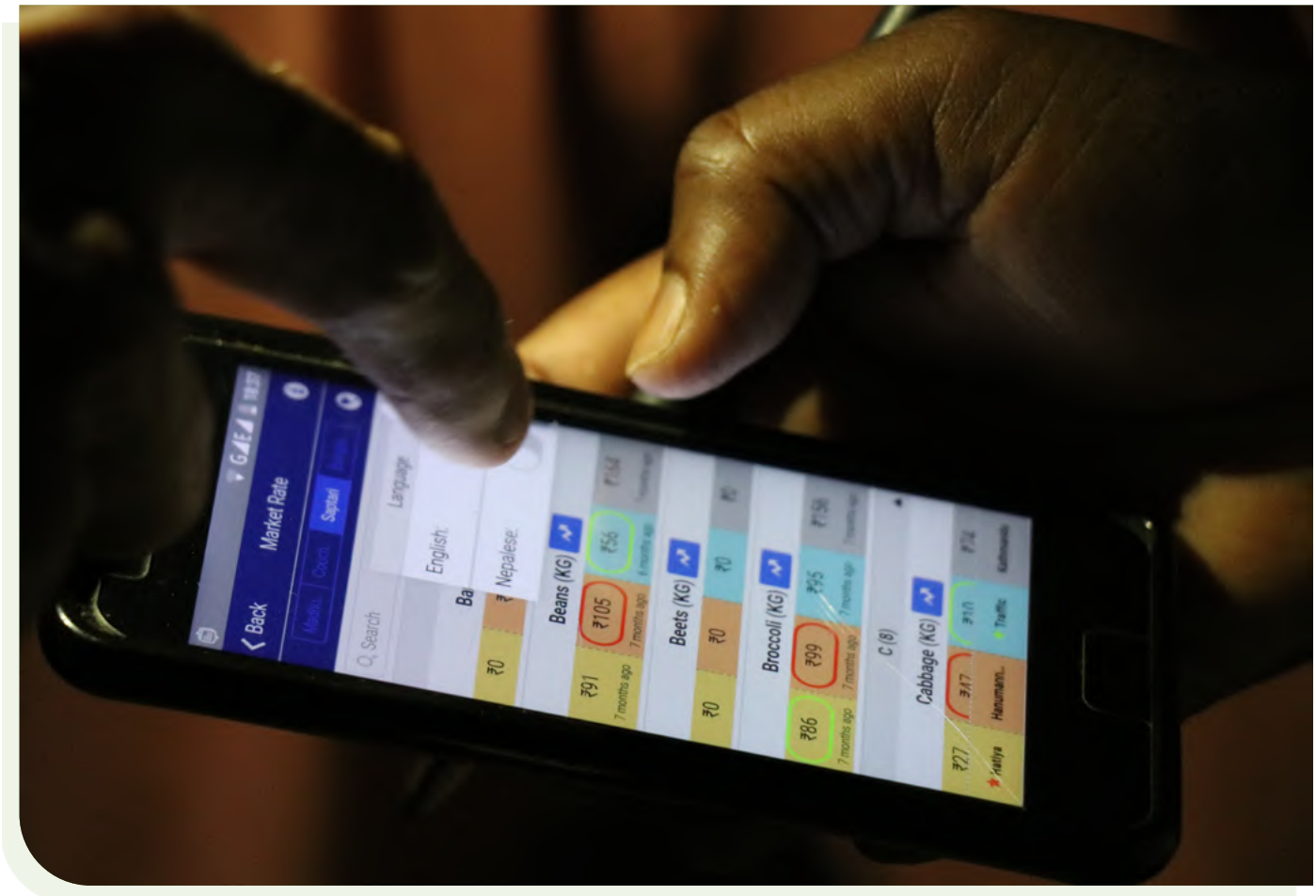
The story of D4Ag adoption across LMICs is a patchwork of regional narratives, each on a unique path on the technology diffusion curve. Some ecosystems are on the rise, blooming with D4Ag innovation and widespread adoption. Others, perhaps jaded by unrealistic expectations or failed implementations, are languishing in the "trough of disillusionment." And yet others are approaching a plateau of maturity, where digital solutions are becoming an integral part of the agricultural landscape.

This report, with its global focus, is both a telescope and a microscope. It acknowledges the idiosyncrasies of each region, aware that a "one-size-fits-all" approach is as inappropriate as it is impractical. Yet, it also explores commonalities that transcend regional boundaries, offering insights that echo in the Andes as resonantly as in the Himalayas.

But in this global study, we also recognize that regions may not be the only or best unit of analysis. Indeed, in the realm of D4Ag, one might find as much common ground between Bangladesh and Bolivia or Brazil and India, as between Bangladesh and India or Brazil and Bolivia. These connections—fostered by similar challenges, opportunities, or stages of digital maturity—form a dynamic web of shared learning and potential collaboration.

The report, therefore, is both an exploration of the present and a guide for the future. It aims to define the path that stakeholders—funders, connectors, knowledge generators, innovators, and advocates—can navigate for the betterment of the sector.

Chapter 2 paints a picture of D4Ag reach and adoption in LMICs and includes an overview



Source: Feed the Future Flickr. Photo credit: Patrick Drown

of key developments across principal D4Ag use cases, unpacking the magnitude and nature of historical growth, while exploring potential for the future.

Chapter 3 takes a closer look at the ecosystem foundations, its main developments, and challenges.

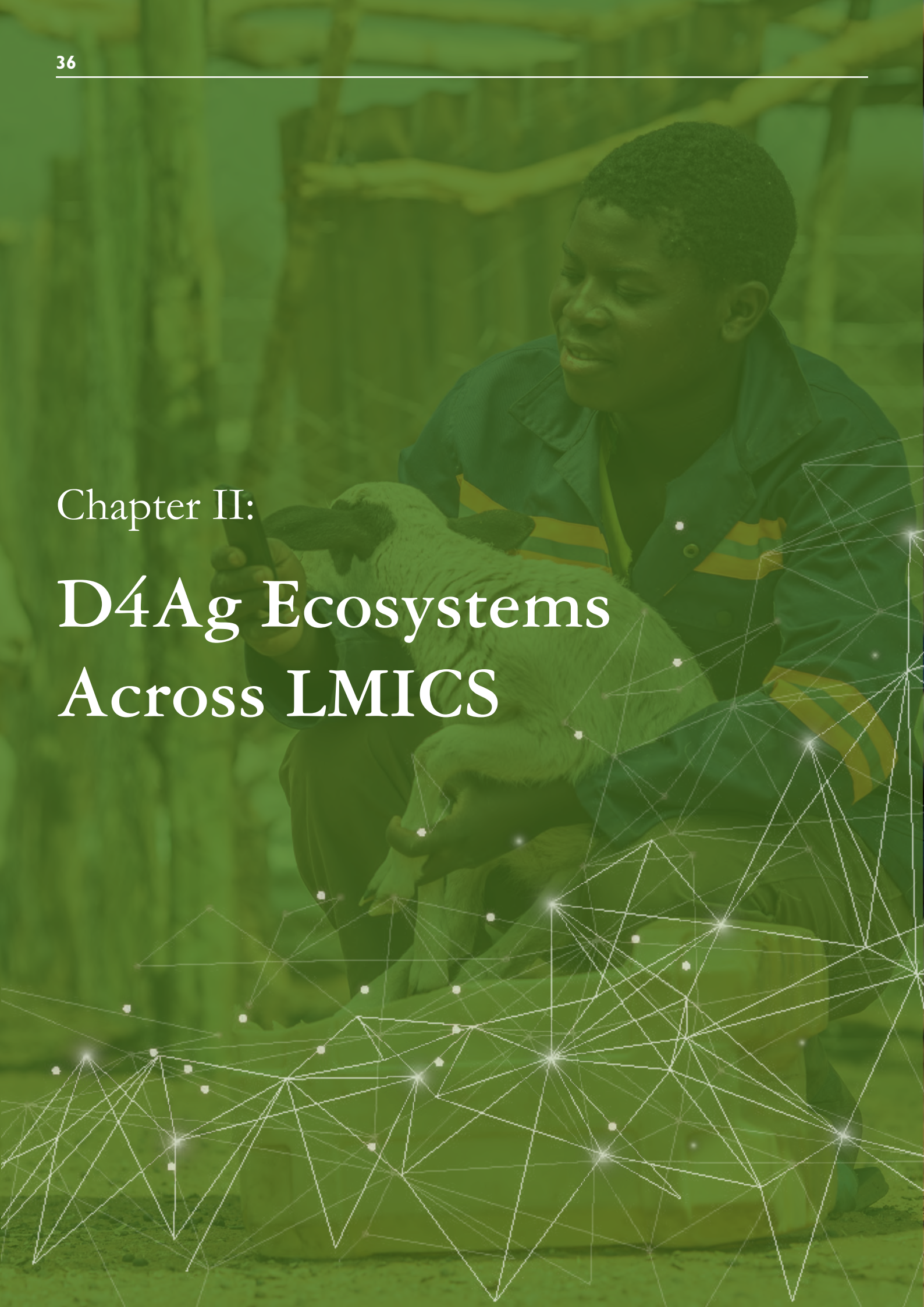
Chapter 4 examines the funding and investment landscape for D4Ag. While this is an oft-trod subject matter, and there are deeper analyses than ours that are publicly available elsewhere, we aim to draw out the nuance of funding gaps across the D4Ag ecosystem as a whole—spanning regions, stakeholders, and stage of innovation.

Chapter 5 unpacks the current understanding (and gaps therein) of impact from D4Ag. Through this chapter, we aim to shed some light on the (still early) base of evidence, call out principal knowledge gaps, and speak to how they can be more effectively reflected and closed, respectively.

Chapters 6 and 7 discuss two key strategies to ensure a just and sustainable future: promoting gender & social inclusion and building climate-smart D4Ag ecosystems. Here, we put the progress and prospects of D4Ag in supporting the achievement of critical goals in the public interest under a microscope and uncover ways in which the full social and environmental potential of D4Ag could be reached.

In Chapter 8, we consolidate and reflect on the preceding chapters by summarizing the most significant challenges constraining the development of inclusive, climate-smart, and commercially viable D4Ag ecosystems across LMICs writ large. It presents our bold predictions for the next decade of D4Ag—what is "likely" and what is "in question." We embark on a qualitative and quantitative exploration of the implications of decisions made today (and in years to come) on sector- and stakeholder-level development outcomes. In particular, we aim to draw out the magnitude of difference in economic, environmental, and social outcomes that could be at stake from the "derailing" of the D4Ag sector (our "lower bound" of reach and impact) as compared to a generally "thriving" D4Ag sector (our "upper bound"). Finally, we offer actionable recommendations for all actors in the D4Ag ecosystem. These are not abstract suggestions but tangible steps specific to unique actors with a stake in the D4Ag sector. For each recommendation, we offer illustrative actions and references to pioneers who have implemented them—whether in D4Ag or analogous settings—from which to learn.

In essence, this report is a guide, a tool, and a call to action. The future of D4Ag in LMICs is within our grasp, shaped by our collective intentions and actions. It is our hope that this report inspires us all to make D4Ag an agent of transformation, driving inclusive, sustainable, and impactful agriculture within LMICs. After all, the journey of D4Ag is our journey too—a journey toward a future where technology becomes a farmer's steadfast ally, and agriculture becomes a sustainable vehicle for progress.



Chapter II:

D4Ag Ecosystems Across LMICS

This chapter introduces the concept of D4Ag, a dynamic field that merges technology and agricultural development. We will delve into the characteristics of a thriving D4Ag ecosystem and the wide-ranging solutions it encapsulates, highlighting key trends across the different D4Ag use cases. A detailed description of the use cases is provided in the Glossary.

Digitalization for Agriculture, or D4Ag, is a broad term encompassing a vast array of digitally enabled solutions aimed at fostering the growth and fortifying the operations of entities throughout the agricultural value chain, from smallholder farmers operating at the grassroots level to multinational corporate agribusinesses exerting influence on a global scale.

In low- and middle-income countries, the D4Ag ecosystem landscape manifests as a diverse, complex, and quickly transforming network. We adopted a fit-for-purpose framework to guide our assessment of the state of D4Ag in LMICs (Figure 1). Ecosystem Foundations comprise the physical, digital, institutional, financial, social, and intellectual building blocks of a well-functioning D4Ag ecosystem. These foundations reflect the resources that sustain both the supply of and demand for D4Ag innovation in respective markets.

D4Ag Use Cases represent the practical application of digital tools in agricultural contexts. These may encompass a broad spectrum of solutions, from supply chain management tools to advisory solutions providing crucial updates to farmers. The development of these use cases considers the specific agricultural systems, value chains, and farming practices prevalent in a region.

Reach and Adoption delves into the diffusion and engagement of these D4Ag solutions among farmers and agricultural stakeholders. Solution penetration is generally influenced by variables such as usability, perceived value, affordability, and cultural suitability.

Household and Macro Impact refer to the effects of D4Ag initiatives at the micro and

Photo credit: WRMS

macro levels respectively. At the household level, these impacts might be represented by enhanced crop yield or income, thereby improving food security. Macro impacts encompass wider economic benefits such as increased agricultural innovation, job creation, enhanced food safety and sustainability, and overall economic growth.

Additionally, we consider two cross-cutting themes that interact with each and every layer of the D4Ag ecosystem: (i) Gender Equality and Social Inclusion (GESI) and (ii) Climate Change. These two themes permeate all levels of the D4Ag ecosystem: from ensuring that D4Ag foundations are inclusive—making technologies and information accessible to all, regardless of gender or social status—to affirming that the positive impacts of digital agriculture are equitably distributed and that agricultural practices are sustainable in the long term.

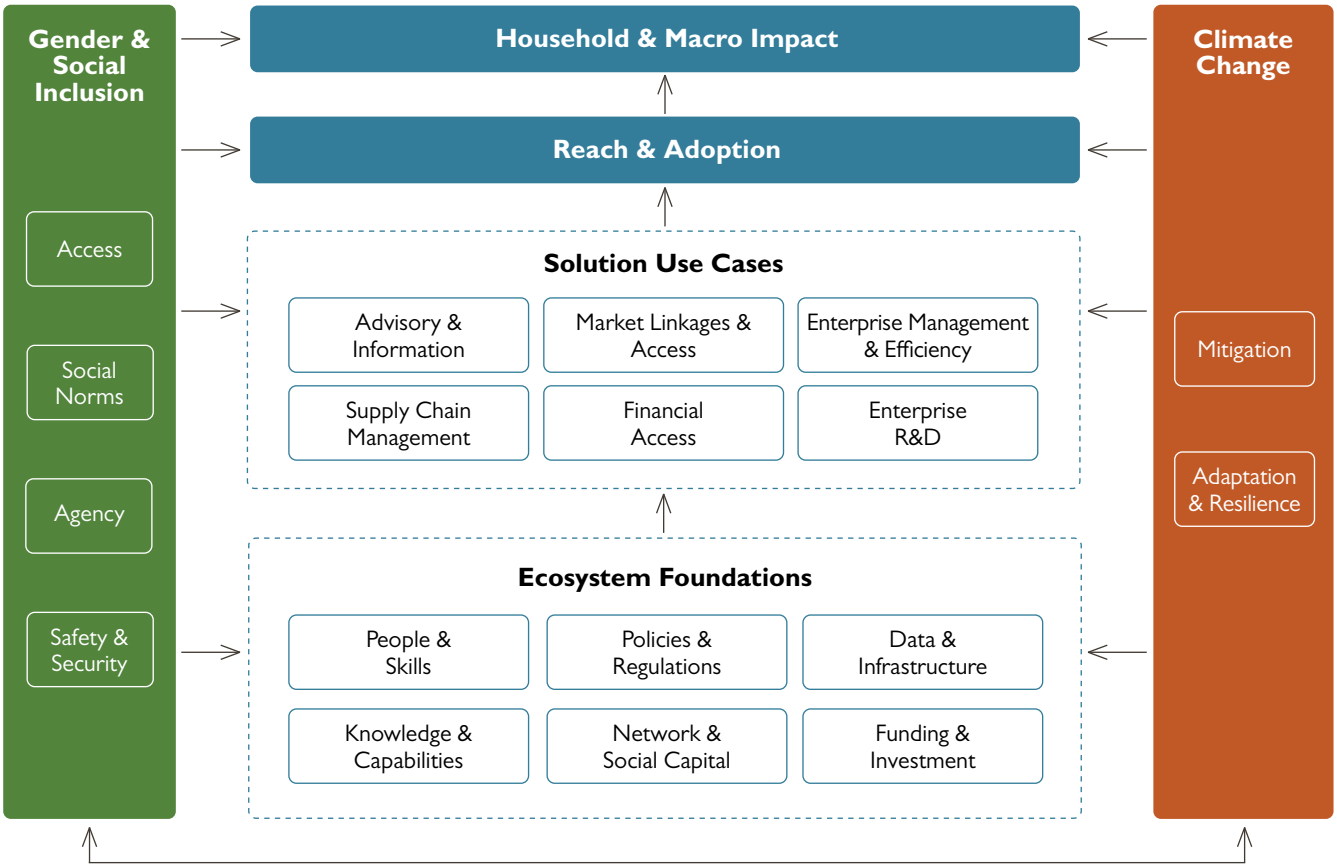


Figure 1. D4Ag Ecosystem Framework

The heart of the ecosystem is shaped by multiple uses for D4Ag solutions, supported by critical D4Ag ecosystem foundations. Our framework identifies six such key foundations:

1 People & Skills:

This area of the framework examines the technological and scientific knowledge available within the supply side of the D4Ag solutions ecosystem, as well as the ability to generate, access, and use this knowledge. It includes R&D capabilities, innovation culture, and the presence of knowledge-sharing platforms.

2 Policy & Regulation:

This pillar describes the role of governmental and institutional policies, regulations, and strategies that can either facilitate or hinder D4Ag implementation. It involves an analysis of the legal and regulatory frameworks for data management, privacy, cyber security, intellectual property, and the promotion of digital solutions in agriculture.

3 Networks & Social Capital:

This component looks at the social relationships, networks, and partnerships that can accelerate or hinder D4Ag initiatives. It involves understanding the interactions among various actors in the ecosystem, such as farmers, technology providers, research institutions, NGOs, and government agencies.

4 Knowledge & Capabilities:

This foundation encapsulates the human capital involved in D4Ag initiatives. It focuses on the capabilities, education, digital literacy, and training of the demand side of D4Ag solutions, primarily farmers. It also examines the demographic diversity, which plays a key role in the adoption and success of D4Ag.

5 Funding & Investment:

This foundation assesses the financial resources available for D4Ag initiatives. It explores sources of funding, investment dynamics, financial products and services relevant to D4Ag, and the financial sustainability of D4Ag initiatives.

6 Infrastructure & Data:

This pillar investigates the physical and digital infrastructure necessary for D4Ag, including connectivity, data centers, platforms, and devices. It also covers the management and use of agricultural data, including data collection, analysis, privacy, and security.

We classified six different D4Ag solution use cases, representing the range of means through which stakeholders across the agricultural value chain leverage digital tools for commercial, social, and/or environmental outcomes.

ADVISORY & INFORMATION

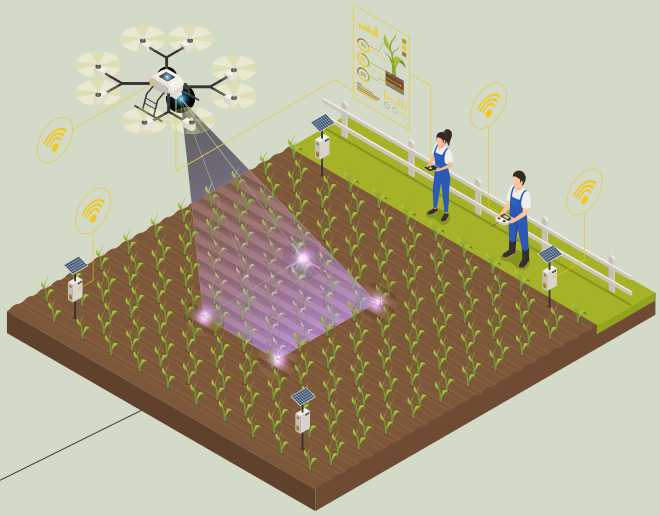
Digital tools (technologies, services, and platforms) providing farmers and value chain stakeholders with real-time information, insights, and recommendations on best agricultural practices.

Value Proposition

By providing timely, localized, and accurate information, these services enable farmers to make data-driven decisions that can improve productivity, provide price transparency, reduce costs, and mitigate risks associated with changing weather patterns and pest/disease outbreaks.

Illustrative Solutions

- Farmer information service
- Precision agriculture advisory
- Participatory advisory
- Macro intelligence



MARKET LINKAGES & ACCESS

Digital tools connecting farmers to buyers, markets, and solution providers upstream and downstream.

Value Proposition

These services reduce information asymmetry and transaction costs in agri-markets, enabling farmers to secure better prices for their produce and access quality inputs more affordably.

Illustrative Solutions

- Digital marketplaces (inputs and outputs)
- Machinery and equipment access
- Digitally enabled value chain integrators
- Climate marketplaces (i.e., for carbon, water, or biodiversity offsets)

ENTERPRISE MANAGEMENT & EFFICIENCY

Digital tools improving the efficiency and effectiveness of farm/business operations and management functions.

Value Proposition

By automating and optimizing various farm/business operations, these tools can lead to significant efficiency gains, cost reductions, and improved profitability.

Illustrative Solutions

- Farm Management Software (FMS)
- Smart irrigation
- Customer relationship management (CRM) / demand management

Table 1. D4Ag Use Cases

SUPPLY CHAIN MANAGEMENT

Digital tools enabling the management of the flow of goods, services, and information across agricultural supply chains

Value Proposition

These tools increase transparency and efficiency in the supply chain, potentially reducing losses, ensuring product quality, and enhancing the ability to meet compliance and traceability requirements.

Illustrative Solutions

- Value chain traceability systems
- Logistics management
- Post-harvest quality control

FINANCIAL ACCESS

Digital tools facilitating access to (increasingly diverse) financial services and risk management tools.

Value Proposition

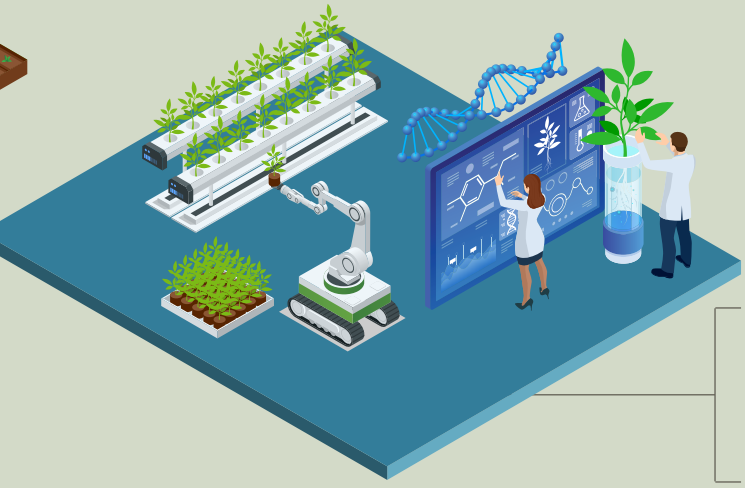
By providing access to tailored financial services, these tools help farmers manage financial risks and invest in productivity improvements.

Illustrative Solutions

- Payments
- Savings
- Credit
- Insurance
- Crowdfunding / peer-to-peer (P2P) lending

ENTERPRISE R&D

Digital tools and platforms supporting the development of new agricultural products and services to meet the evolving needs of farmers and other stakeholders across agricultural value chains.



Value Proposition

By fostering innovation, these tools enable the development of new, better-performing products and practices that can boost agricultural productivity and sustainability.

Illustrative Solutions

- R&D digital support tools
- Seed/genome editing digital platforms
- Market research and analytics
- Open innovation platforms
- Digital prototyping and automation
- Discovery platforms

The D4Ag sector has matured significantly over the past decade, leading to an increase in not only the number of but also types of solutions offered to smallholder farmers. However, the sector lacks a standardized taxonomy to categorize these solutions. While the six use cases outlined above are intended to represent the ways through which stakeholders can access D4Ag solutions (building on CTA's "The Digitalisation of African Agriculture Report 2018–2019"), they are not intended to serve as a comprehensive taxonomy of the types of solutions in the market.

In parallel to this report development, AgFunder, AgBase, and ISF Advisors have co-developed an industry-leading taxonomy to provide an overview of the types of D4Ag solutions that exist in the market today. This new taxonomy is intended to promote collaboration and ease of data sharing across sector stakeholders. For additional information on this taxonomy and its relation to the six use cases outlined in this report, please refer to Appendix 2.

ADVISORY & INFORMATION

Advisory & Information solutions provide farmers with real-time information, insights, and recommendations on best agricultural practices. This information can be invaluable in helping farmers make informed, data-driven decisions that improve productivity, reduce costs, and mitigate risks. These services' value hinges on accurate data sourcing, advanced analytics capabilities, local language content, and effective dissemination channels, such as mobile apps and SMS services.

Figure 2. Advisory & Information Selective Solutions Snapshot (Illustrative)

Source: Feed the Future Flickr

Growth in Complexity and Precision: The initial phase of development in the Advisory & Information domain was characterized by the digitization and dissemination of existing public information, such as agricultural and market information and advice provided by governmental bodies like ministries of agriculture. The primary goal was to extend the reach of this valuable information to farmers and other stakeholders who might otherwise not have had access to it. However, these early efforts often faced challenges related to content relevance, timeliness, and the capacity of farmers to apply generalized information to their specific contexts.

As the field has matured, fueled in part by increased funding and technological advancements, there has been a sustained shift toward more complex and precise insights, allowing for decision-making support better tailored to individual farmers' unique needs and local conditions. Partnerships between tech companies, governments, and NGOs have resulted in platforms that combine data from various sources to provide a more holistic view of agricultural practices and tailored insights. Moreover, the progression of AI and ML technologies alongside geospatial imagery has been a game-changer in the Advisory & Information landscape. These advanced technologies have enabled more complex analysis, predictive modeling, and the personalization of advice. For instance, AI-driven models can now predict weather patterns, pest infestations, or crop diseases with remarkable accuracy, enabling farmers to take preventive measures, enhance productivity, and reduce risks.

Initial Dominance of "Pure Advisory" Tools and Subsequent Failures: Early in the evolution of D4Ag, pure digital advisory solutions held a prominent place in the market. However, this approach encountered significant obstacles, particularly in the context of LMICs. Farmers' low willingness and ability to pay for digital advisory services that were usually provided by the public sector free of charge has challenged the financial viability of such platforms. Many such platforms were, and still are, dependent on donor or government funding, as investors often struggle to see a clear path to expected rate of financial return. It has not been uncommon to see digital advisory platforms' stunted development or shutdown with the close of a public / social program,. Recent years have seen greater prevalence of and shifts toward bundling advisory services with other offerings, such as market access, financial access, or supply chain management tools. This bundling resulted in advisory services often being offered free of charge, while revenues are derived from other service offerings. We will delve deeper into such business model shifts later in this chapter.

Discomfort with Digital-Only Solutions: Our interviewees have commonly quoted the lack of farmers' trust in digital tools—reflecting cultural preferences, literacy levels, lack of incentives, and perhaps experiences with irrelevant or incorrect advice—as a significant barrier to promoting digital advisory solutions. This forced many innovators in LMICs to offer some form of in-person or digital support to their users. These hybrid models combine the scalability of digital tools with the trust and context-specific insights that personal interactions can provide.

Photo credit: Upaj

Whether through local agents, community meetings, video conferences, or other means, this human touch has proven essential in building trust and ensuring that the advice is understood and applied effectively. We will delve deeper into the role of intermediaries in supporting digital solutions' reach and scale in LMICs at the end of this chapter.

MARKET LINKAGES & ACCESS

Market Linkages & Access services use digital tools to connect farmers with buyers, markets, and other value chain stakeholders. By reducing information asymmetry and transaction costs in agri-markets, these services can enable farmers to secure better prices for their produce and access quality inputs more affordably. These tools also provide new avenues to incentivize and compensate farmers for climate- and industry-friendly practices. The effectiveness of these services relies heavily on a large network of buyers and sellers, a trustworthy and transparent platform, efficient logistics, and a deep understanding of local markets. Moreover, the availability of physical infrastructure such as roads, warehousing, and cold supply chain facilities is crucial for growth of these solutions in the LMICs context.

Figure 3. Market Linkages & Access Selective Solutions Snapshot (Illustrative)

From "Transparency" to "Transactional": Initial platforms in this category primarily served as channels where farmers could find information about prevailing market prices and potential buyers. As these platforms scaled and technology advanced, especially in areas like fintech/ payments and blockchain, the scope broadened, enhancing the value proposition for end users.

Many Marketplaces: Market Linkages & Access tools are opening new avenues for farmers to generate value from, and add value to, their assets. While early waves of innovation were populated mainly by marketplaces for offtake of agricultural products, new marketplaces tap into broader forms of value—i.e., access to inputs, leasable machinery and equipment, and even carbon credits.

Attracting "Converts" from across the D4Ag Landscape: As mentioned before, in the LMICs context, monetizing many service offerings—such as farmer advisory—has proven to be challenging for innovators. On the other side, commercial viability of Market Linkages platforms (specifically opportunities to charge both sides of platform users for transactions), resulted in this use case emerging as a convergence point for many solutions. These platforms often constitute the bridge between services rendered and a transaction, whether it is selling produce, accessing finance, or leasing equipment.

Increasing Interest of Investors: Digital marketplaces and value chain integrators are leading the way in attracting private investments in LMICs: We estimate that Market Linkages & Access tools have raised more than a quarter of private investments in these regions in 2021. Companies like **Frubana** (Colombia), **DeHaat** (India), **Jai Kisan** (India), **Captain Fresh** (India), and **ThriveAgric** (Nigeria) all raised substantial investment rounds in 2022 with amounts comparable to US- and EU-based innovators.

Lack of Supporting Infrastructure Curbing Potential: Often, a lack in LMICs' essential infrastructure—such as warehouses, modern logistical solutions, and cold supply chain facilities—creates barriers for growth of

Photo credit: Verific8

Market Linkages platforms and often skews the direction of innovation in the D4Ag space. Many market linkage platforms, for instance, opt for the less challenging route of focusing on non-perishables to avoid the complexities and uncertainties associated with perishable goods, leaving farmers of those goods behind.

ENTERPRISE MANAGEMENT & EFFICIENCY

Enterprise Management & Efficiency tools provide the digital means to automate and optimize various farm/business operations, which can result in considerable efficiency gains, cost reductions, and improved profitability. User-friendly software interfaces, integration with other farm data sources, and cost-effective solutions are all crucial elements for these services.

Limited Availability of Ag-Specific CRM Tools in LMICs: The development of ag-specific CRM tools appears to be lagging in LMICs, contrasting with trends in the developed markets, especially in the USA and Europe. Traditional CRM systems are not always adaptable to the unique needs and workflows of the agricultural sector; therefore, an opportunity exists to develop CRM systems that are specifically tailored to the agricultural context in LMICs, considering the distinctive relationships between farmers, suppliers, and customers.

Improving Coverage Across Value Chains: With the strengthening of mobile connectivity and the integration of IoT, the scope of enterprise management has expanded, covering various stages of the supply chain, from on-field monitoring to distribution and retail. Farm management tools are now expanding besides cropping, with innovators like **eFishery** rapidly digitalizing agricultural communities.

Limited Application of Farm Management Software to Smallholder Farms: Many D4Ag tools in this category have found more success in serving large-scale, downstream players like processors, distributors, retailers, and commercial farms. These organizations often have the resources to invest in advanced technologies, allowing them to benefit from the sophisticated insights and automation that these tools offer, while uptake of FMS by smallholders remains very limited.

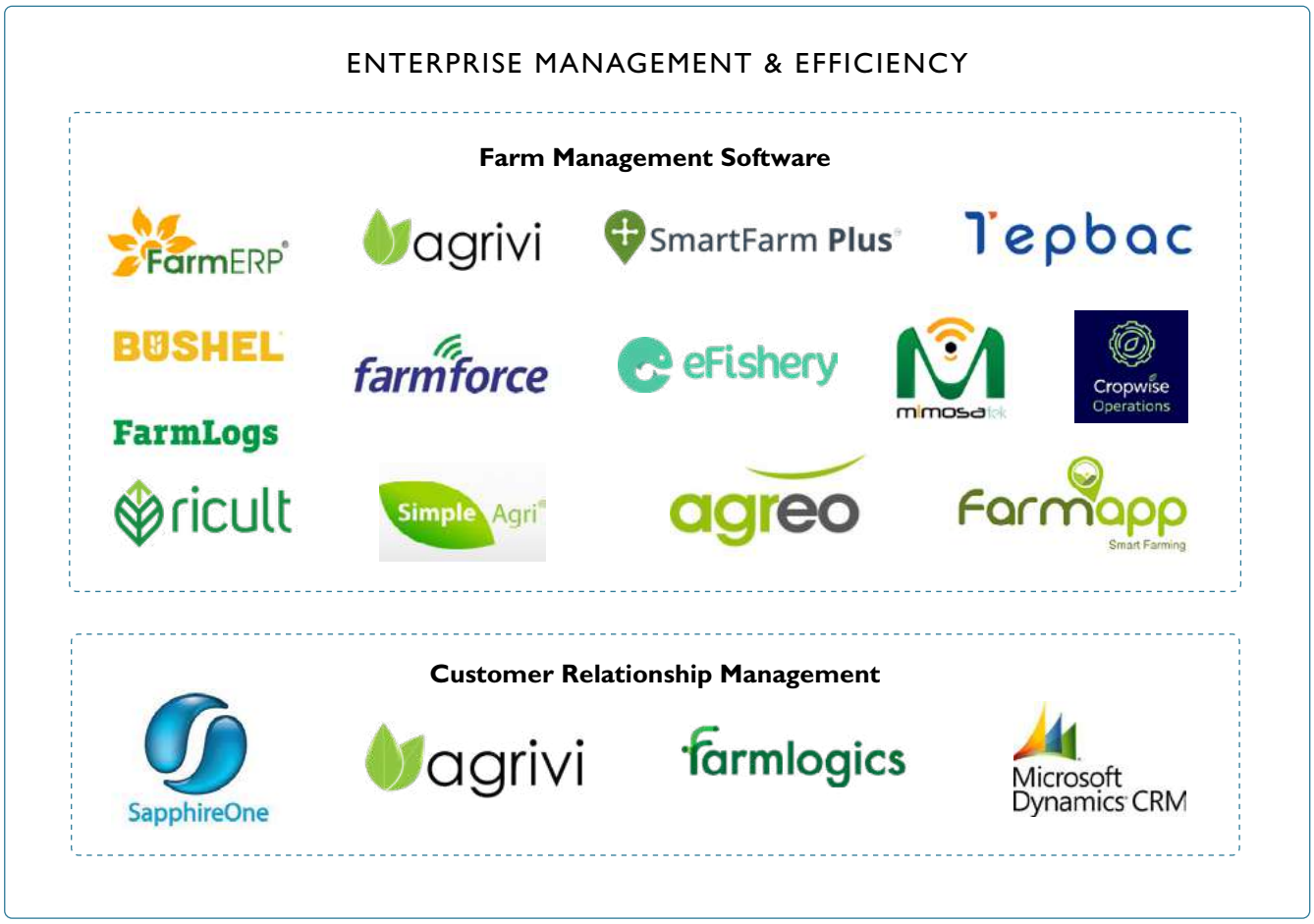


Figure 4. Enterprise Management & Efficiency Selective Solutions Snapshot (Illustrative)

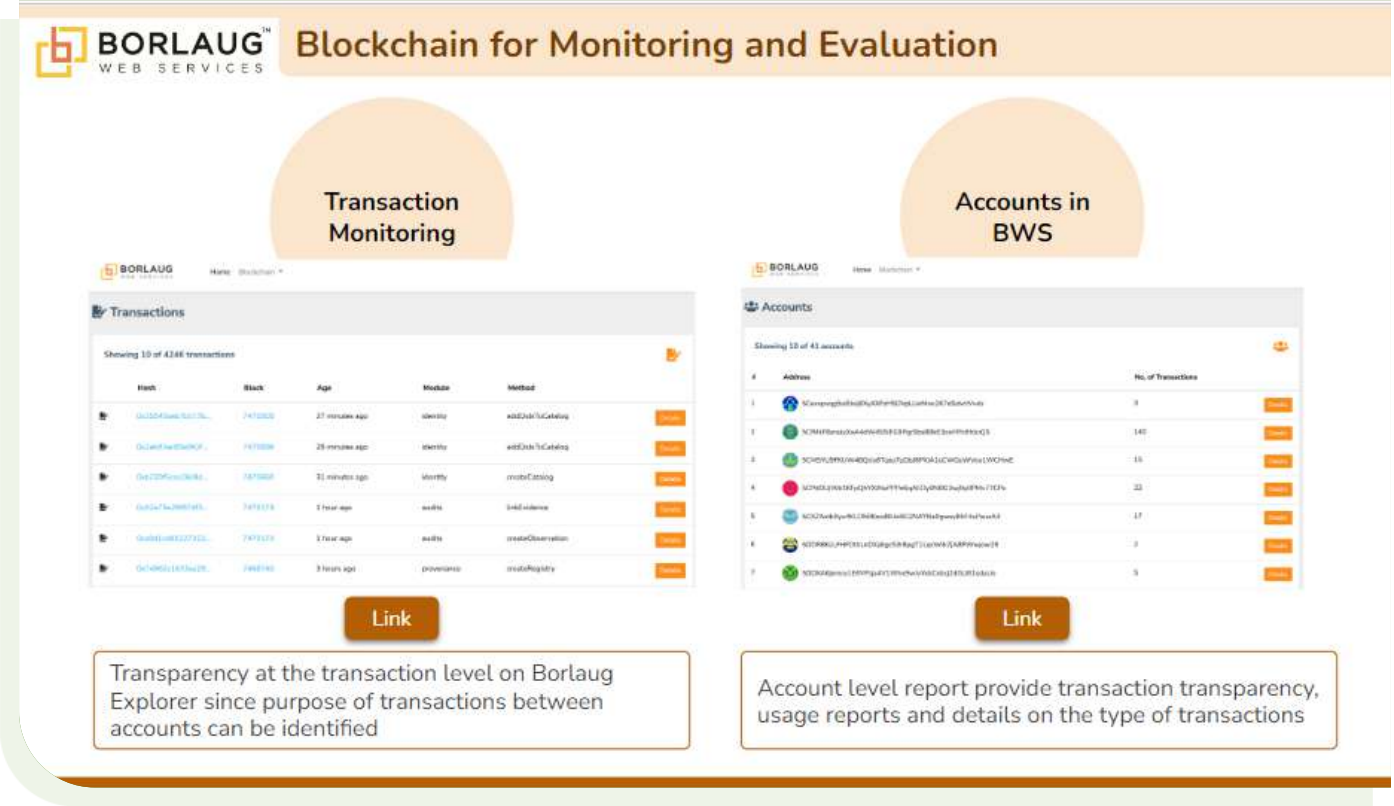


Photo credit: Borlaug Web Services

SUPPLY CHAIN MANAGEMENT

Supply Chain Management services is another significant category, offering digital tools to manage the flow of goods, services, and information across agricultural supply chains. By increasing transparency and efficiency in the supply chain, these tools can reduce losses, ensure product quality, and enhance compliance and traceability. To be effective, these services need to integrate with other systems, have robust data capture and analytics capabilities, and ensure efficient logistics.

Use of Advanced Technologies and Data Analytics: The broader availability of advanced hardware (IoT, tracking devices, etc.) has allowed for real-time monitoring of perishable goods throughout the supply chain, quickly transforming traditional supply chain models. From the software side, analytics tools have begun to harness vast amounts of data to provide valuable insights into demand patterns, allowing for data-driven decisions in planning production and distribution. Blockchain-based solutions have become the norm for much of the industry focused on traceability, provenance, and supply chain integrity.

FMCG Companies Driving Innovation: Leveraging their need for efficient, real-time inventory management and distribution, FMCG companies have been at the forefront of adopting and implementing digital supply chain management tools and also spurring further innovation in the sector.

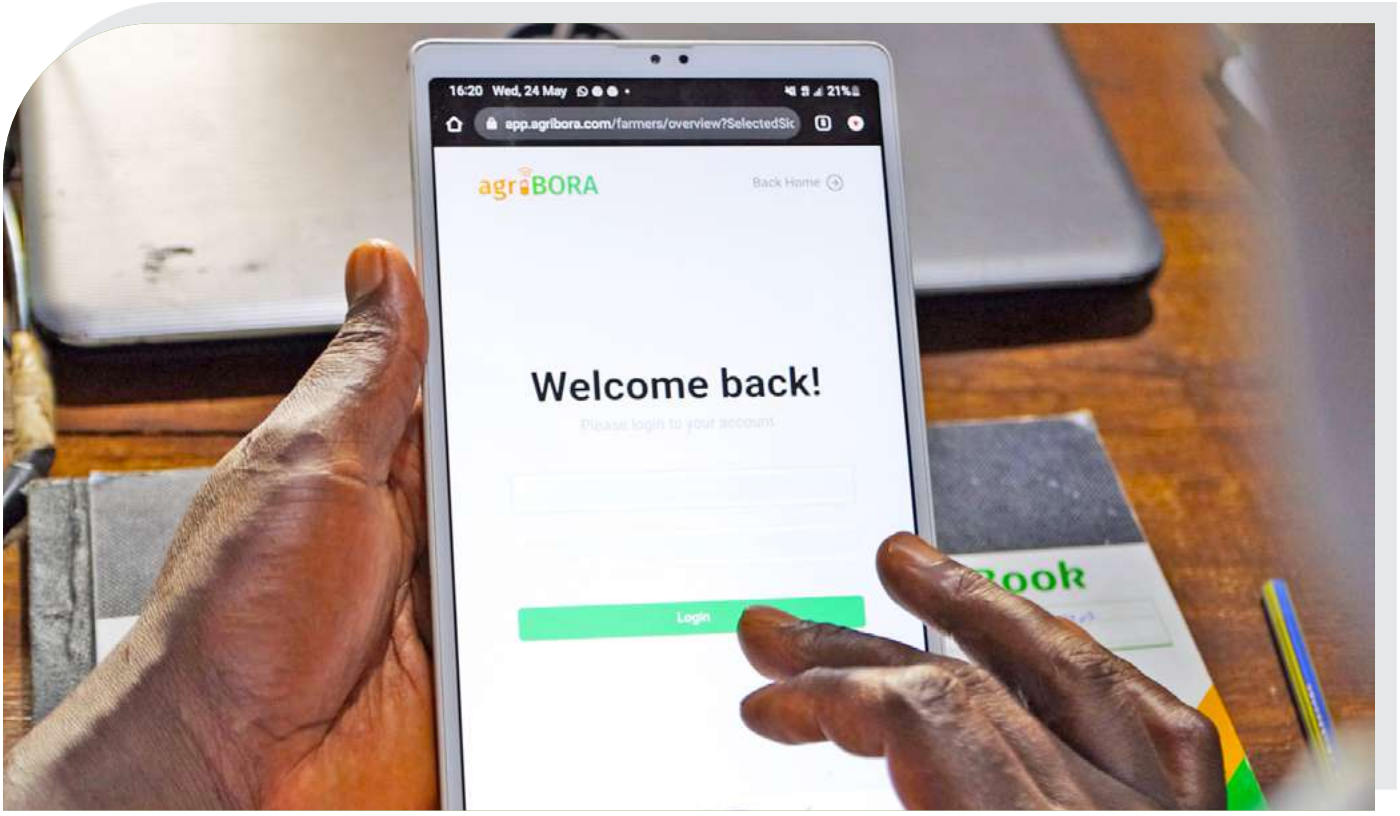


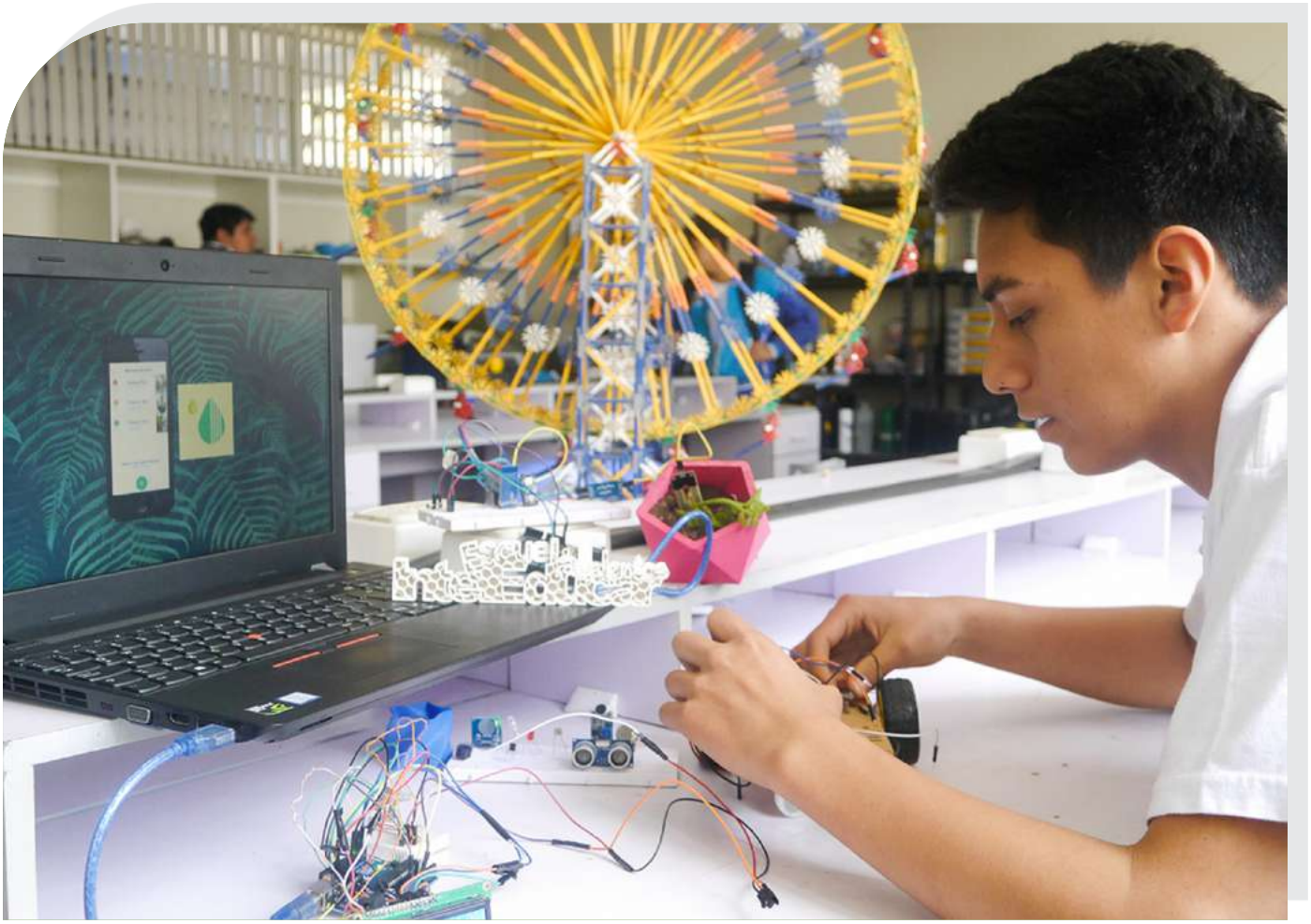
Photo credit: agriBORA

Figure 5. Supply Chain Management Selective Solutions Snapshot (Illustrative)

FINANCIAL ACCESS

Financial Access services use digital tools to provide access to an increasingly diverse range of financial services and risk management tools. These tools create value by enhancing financial inclusion, providing farmers, their collectives, and SMEs with access to credit, facilitating savings, enabling seamless payments, and providing insurance products designed for the agricultural sector. They can also help farmers manage financial risks, invest in productivity improvements, and smooth out income fluctuations. Partnerships with financial institutions, robust risk assessment models, user-friendly digital interfaces, and high levels of trust and security are all critical factors for these services.

Figure 6. Financial Access Selective Solutions Snapshot (Illustrative)



Source: Feed the Future Flickr. Photo credit: Maria Luisa Ramirez Cruz

From Mobile Payments to Diverse Financial Tools: Initially focusing on digitizing payments, the sector has rapidly expanded to include a variety of tools, such as credit and insurance, fueled by improved data availability and technological advancements.

Technological Intensity: There has been a noticeable increase in the tech intensity of tools that support financial service providers in enhancing their services. Records of smallholder farmers selling and purchasing goods via Market Linkages platforms, as well as the broader availability of remote sensing technologies for the collection of farm-level data, have allowed for the development of credit scoring models that can assess smallholder farmers at scale.

Diverse Clients Served: Alongside the technological advancements, there has been a significant expansion in the diversity of clients serviced. From input retailers and traders to various entities across the value chain, the reach of digital financial tools has broadened. This presents opportunities for further exploration and innovation in how these services are delivered, even to digital service providers themselves.

Unstable Regulatory Landscape: Regulation has played both an enabling and constraining role in the development of financial access digital tools for agriculture. In some instances, regulations have opened new categories for fintech operators; while in others, they have imposed limitations, such as levies on mobile payments. Interestingly, regulations have also driven innovation and creativity in some regions, such as the trend of lending "in kind" rather than cash in Indonesia.

ENTERPRISE R&D

As the technology has advanced and D4Ag ecosystems in LMICs have strengthened, a new use case in digital agriculture has emerged. In the Enterprise R&D category, digital tools and platforms support the development of new agricultural products and services to meet the evolving needs of farmers and other stakeholders.

By fostering innovation, these tools enable the development of new, better-performing products and practices that can boost agricultural productivity and sustainability. Strong R&D capabilities, access to multidisciplinary expertise, partnerships with research institutions, and adequate protection of intellectual property are key to these services' success.

Product Development: Technological advancements and availability of sophisticated technologies like AI and ML have allowed for the acceleration of product development and R&D, bringing seed and genome editing, as well as microbial discovery applications to LMICs. Companies like **Benchling** and **Oerthbio** are offering platforms that allow scientists and researchers to collaborate, manage data, and streamline their workflows. Such platforms include **Absolute Ag** (bioscience platform, India), **UPAJ** (ML and data analytics for risk-assessment, insurance, and real-time advisory, India), **BioHeuris** (gene editing platform, Argentina), and **Sound Agriculture** (bioscience platform, US-based with operations in Brazil and Argentina).

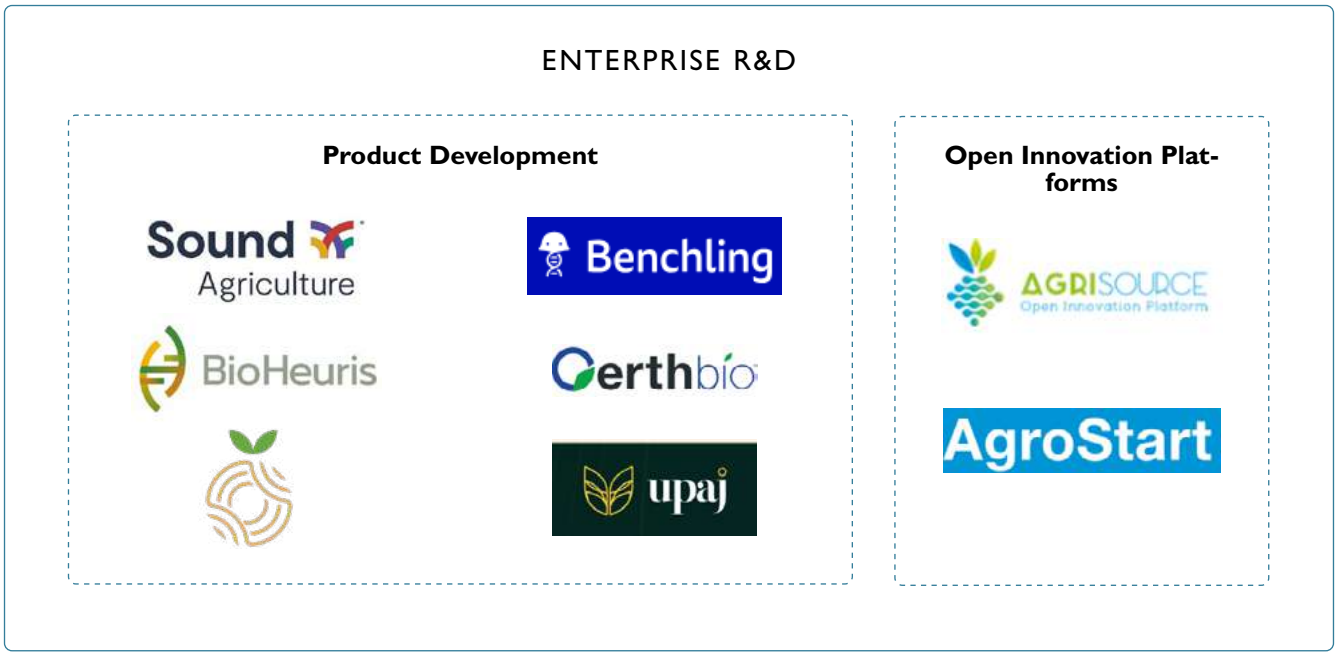


Figure 7. Enterprise R&D Selective Solutions Snapshot (Illustrative)

Source: Feed the Future Flickr. Photo credit: Nicolas Réméné, OKO

Open Innovation Platforms: Emphasizing collaboration and cross-sector engagement, open innovation platforms like BASF's **AgroStart** and **Agrisource** are fostering a culture of shared creativity and innovation in agriculture. By connecting researchers, entrepreneurs, farmers, and industry experts, these platforms are stimulating the development of new ideas, technologies, and solutions tailored to the specific needs and challenges of the agricultural sector.

While the underlying technologies for these innovations are predominantly developed in the higher-income countries, the advent of digital tools is allowing value chain players in LMICs to leverage them. The reach of these sophisticated technologies and platforms is expected to expand in LMICs in the coming years, enabling local agricultural sectors to benefit from the latest scientific and technological advancements.

"Super Platforms"

While not a distinct use case on its own, the concept of D4Ag "super platforms" has long been a subject of interest and debate within the D4Ag community. We have adopted the definition of D4Ag "super platform" from "The Digitalisation of African Agriculture Report 2018–2019" authored by CTA and Dalberg Advisors, which describes this type of solution as "platforms linking farmers to buyers and to the broader ecosystem of finance, advice, and other services, thereby eliminating layers of intermediaries and creating immediate economic value."

Super platforms in the D4Ag ecosystem are not merely a collection of distinct services bundled together on a single platform; rather, they thoughtfully integrate complementary services, where each component has the potential to enhance the others, thereby generating significant added value. These platforms, in effect, are creating a "one-stop shop" for farmers, simplifying their interactions with various elements of the agricultural value chain. The holistic approach to service provision not only reduces the complexity for farmers but also drives efficiency in the delivery of services.

It has been often preached and hypothesized that such super platforms comprise the model upon which D4Ag will converge, but it has not generally come to be. D4Ag super platforms in LMICs are still struggling with achieving a critical mass of users. This challenge is often referred to as the "chicken and egg" problem, where buyers (such as agribusinesses, traders, or consumers) want to join a platform if there are enough sellers (farmers or farmer groups), and vice versa. Moreover, even after achieving a critical mass, sustaining this scale over the long term is another challenge, as it requires continuous engagement and value delivery to both sides of the platform. Platforms need to constantly innovate and adapt to the changing needs of their users to keep them engaged and active on the platform, presenting a significant challenge for the innovators.

Besides, critics have voiced concerns about the potential excessive market dominance, where further consolidation of dominant agribusiness via digital tools will allow them to essentially control whole markets.

> *"There are huge players in this space from the private corporate sector. And what they do is a vertical integration approach. So, I have farmers that I provide inputs to, then I buy their produce back, I process it. And then I also have control of the market. And that's where you see the most successful examples of digital transformation. […] A fertilizer company now suddenly does everything, even agricultural advice, so they control the entire value chain. And that could really affect how the food system works and gets us in a much worse place than where we are now."*
>
> Research Institute, USA

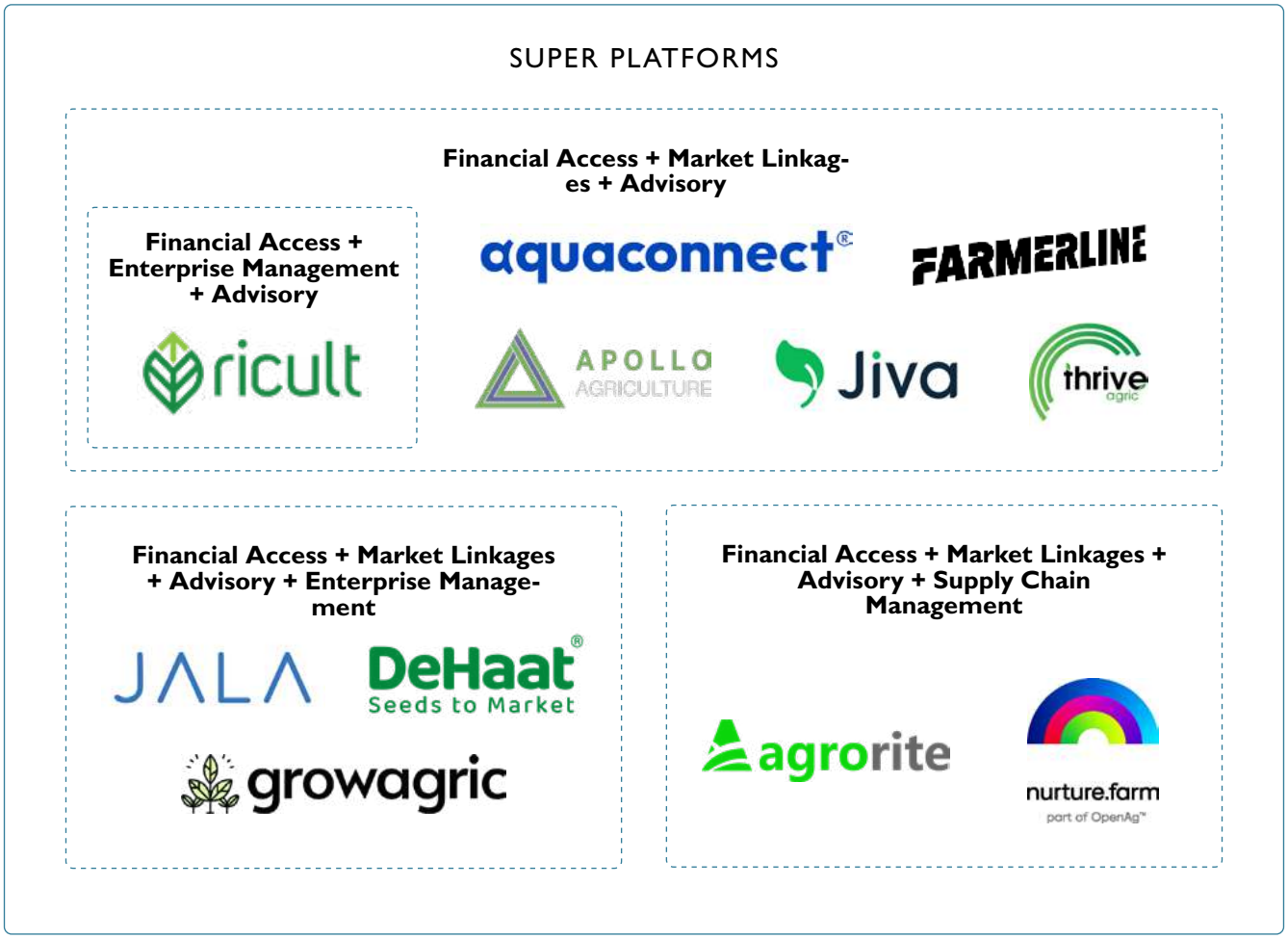


Figure 8. Examples Of Selective D4Ag Super Platforms (Illustrative)

Even though we have seen some significant growth in this category, we have also witnessed the opposite examples of growth of targeted solutions, like **Solinftec** in Brazil, shifting from a broad focus to specific advisory solutions and finding success in that niche. While the pursuit of creating super platforms is widespread, there is no definitive evidence to suggest that this is the only or even the best strategy. What is emerging is a more nuanced landscape where super platforms exist alongside more focused solutions.

OVERVIEW OF DIFFERENT BUSINESS MODELS BEHIND THE USE CASES

Digital tools, specifically in the agricultural sector, often face some unique challenges from the business model side. A lack of supporting infrastructure in the rural areas; high costs of developing, testing, and scaling digital solutions; and the limited ability of smallholder farmers—often the primary beneficiaries of these tools—to pay for these services can create a significant funding gap that needs to be addressed by the business model. In an evolving digital landscape, several distinct business models are commonly used by D4Ag innovators (Figure 9).

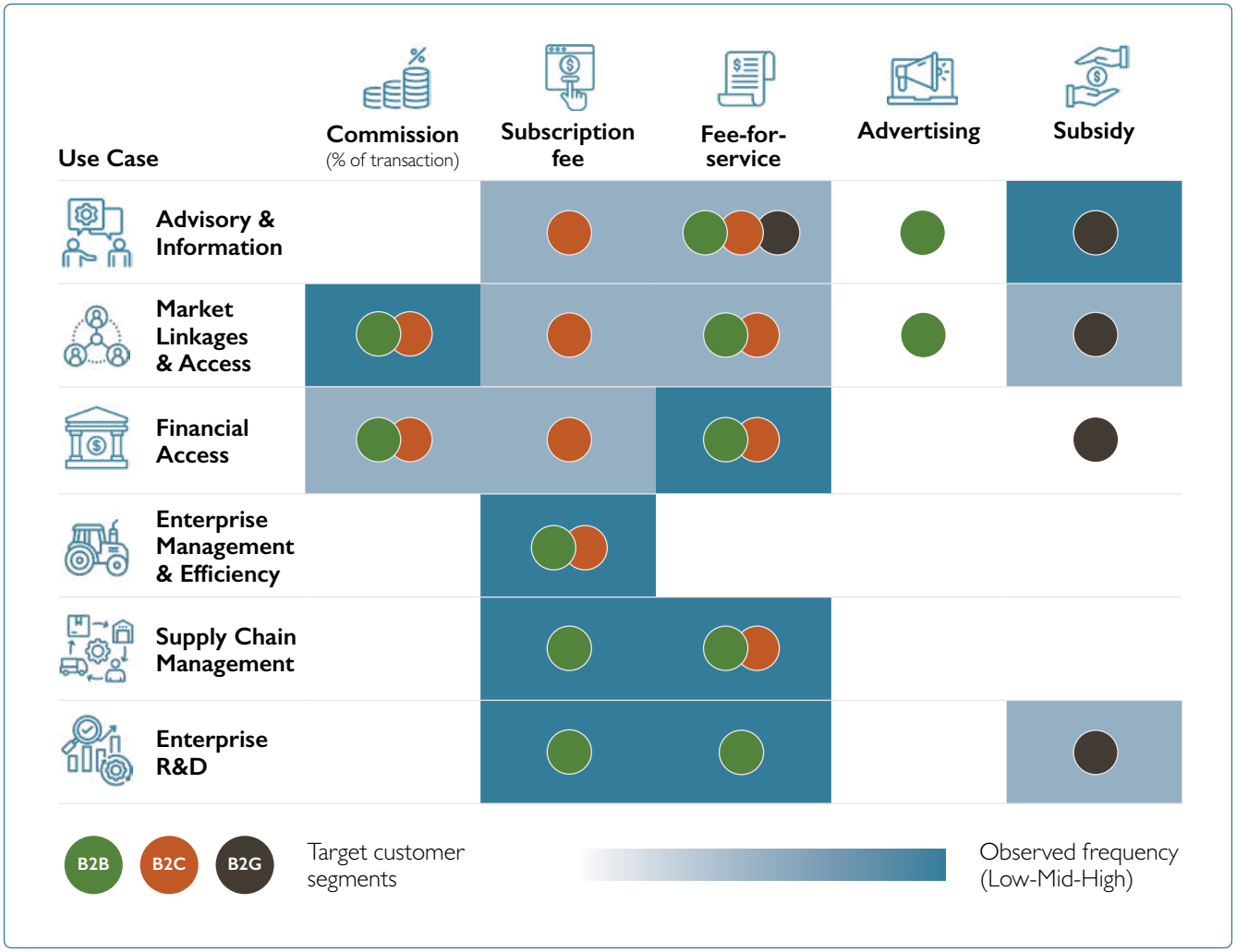


Figure 9. Overview of Business Models Behind D4Ag Solutions

First, **commission-based models**, wherein the platform charges a commission on transactions or profits from selling physical or digital products or services, are commonly deployed. Second, there is a **subscription-based model** where a regular fee is charged for access to the services. Third, there is a **fee-for-service (usage fee) model**, where a one-time fee is charged for using a particular service. Fourth, a business model built around the sale of **advertisements** is also observed. This entails monetizing the platforms by selling ad spaces to interested parties. Lastly, some D4Ag businesses generate income through **direct subsidies**. This model primarily involves securing project-based funding or grants from development organizations, governments, or NGOs.

It is crucial to understand that these business models are not mutually exclusive. Many D4Ag enterprises employ hybrid models, cleverly combining several revenue streams to optimize their income and reduce risk.

Besides the five abovementioned models, a **"freemium"** business model is used by some D4Ag innovators, particularly in the domain of advisory services, enterprise management, and financial access platforms. This model offers a basic level of service free of charge to a large user base, while charging for premium features or services to a smaller segment of that base who find value in the additional features. For example, a D4Ag platform may offer basic weather and market price information for

Source: Feed the Future Flickr. Photo credit: Miles Sedgwick, Rana Labs

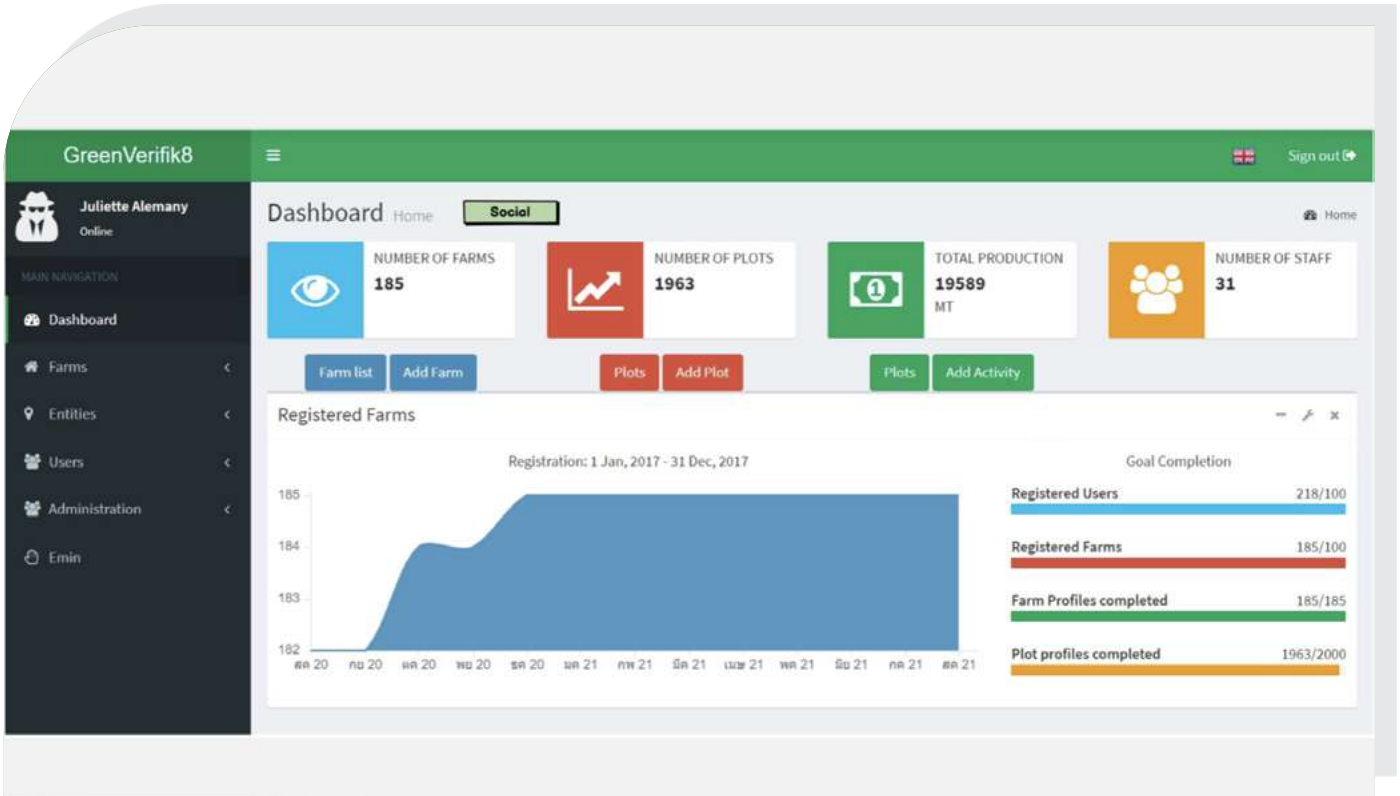
free, but charge for personalized advisory or advanced analytics. The freemium model can help D4Ag startups to rapidly acquire a large user base by reducing the barriers to entry, which is particularly important in the D4Ag sector where farmers can be hesitant to adopt new technologies. It also helps the innovators to establish a strong presence in the market and can lead to network effects, where the value of the platform increases as more users join, leading to more data and better services.

For the digital Advisory & Information services, they are often offered free of charge and led by governments and NGOs without generating any revenue. For-profit D4Ags also tend to follow a model where the payment for services does not come directly from the smallholders, as this approach has proved to be difficult to scale largely due to the recognition that smallholder farmers often have limited resources and/or desire to pay for agri advisory services. As a result, even though some innovators are exploring cooperative-subscription or freemium models, there is a clear pivot to embedding advisory services into one-stop solutions or "super platforms." In these cases, the advisory services are often offered free of charge, while other features of the platforms are monetized.

> *"[Digital] advisory is very well consumed when it's done well for farmers. The challenge usually comes in the business model: it's very hard to get farmers to pay for it. So, while farmers would use it a lot and engage with it, they're also not willing to pay for it. So, there's zero business model there, right? But by bundling it, with the digitized payments and other financial services it builds a business model for the provider themselves. They get the stickiness with the advisory, but then they're getting fees from other services. And the farmer is not paying for advisory, but that's what they're going to use the most. And then they get kind of exposed to these other tools and services that they find useful."*
>
> GESI Expert, the UK

For Financial Access platforms, a diverse array of business models has been observed, reflecting the wide-ranging services they provide. Most direct financial services like digital lending and insurance often operate on a fee- or interest-based model. For example, digital lending platforms may charge interest on the loans they offer, while digital insurance services often collect premiums. Furthermore, P2P lending and crowdfunding platforms typically operate on a commission-based model, collecting a small fee for each transaction made on the platform. However, for many financial access platforms, partnerships with financial institutions play a crucial role, and these partnerships may lead to shared revenue models or funding support.

Regarding Enterprise Management & Efficiency tools, these typically operate on a subscription or software-as-a-service (SaaS) model, with users paying a regular fee to access the software. However, to increase adoption, some providers



Brand's dashboard. Source: Verific8.

offer a tiered model where basic features are available for free (freemium model), and users can pay for additional features or capabilities. In some cases, enterprise management tools can also be part of larger "super platforms," where multiple services are offered, and revenue comes from several sources.

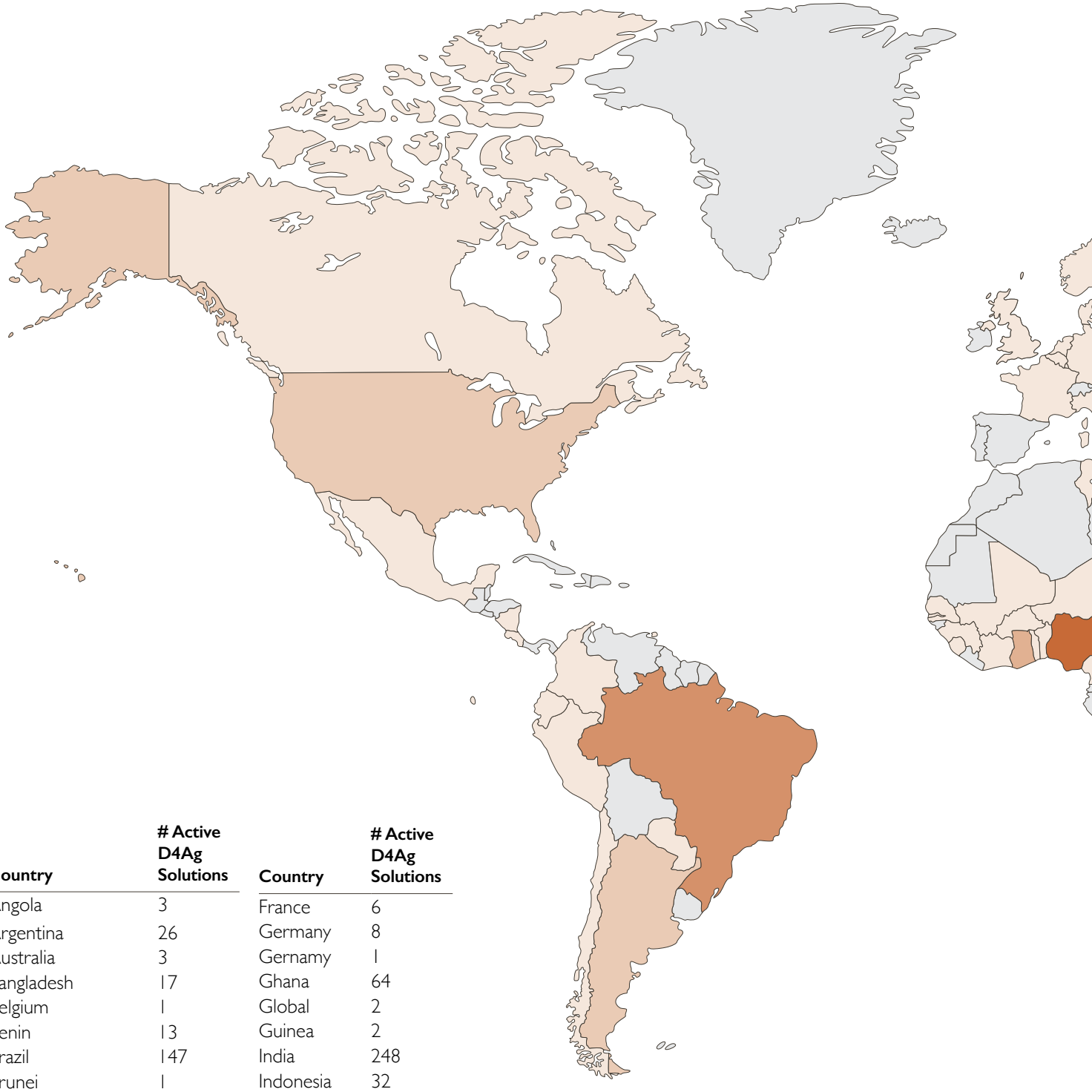
Supply Chain Management solutions often employ a variety of business models. Many of these platforms operate on a commission or fee-based model, taking a small portion of each transaction conducted through the platform. This is particularly common for logistics management platforms. Traceability systems usually operate on a SaaS basis, or they might be funded through partnerships with larger agribusinesses or retailers who have a vested interest in ensuring supply chain transparency. Post-harvest quality control platforms often operate on a service fee model, charging for each batch of produce tested or monitored, or on a SaaS model.

When it comes to Market Linkages & Access tools, they often function on a commission-based model, with the platforms taking a percentage from each transaction made. Some digital marketplaces may also monetize through advertising, featuring particular products or sellers for a fee. In addition, machinery and equipment access platforms often operate on a usage fee model, charging farmers based on the time or extent to which they use the machinery or equipment.

CURRENT LANDSCAPE: STATE OF D4AG REACH AND ADOPTION IN LMICS

In the past decade, the global D4Ag sector has shown a rapid expansion, though with a decelerating pace. **As of 2022, we have identified 1,357 active D4Ag solutions in LMICs.**

Source: Feed the Future Flickr. Photo credit: Verific8



Country	# Active D4Ag Solutions
Angola	3
Argentina	26
Australia	3
Bangladesh	17
Belgium	1
Benin	13
Brazil	147
Brunei	1
BurkinaFaso	4
Cambodia	5
Cameroon	12
Canada	2
Chile	8
Chilie	1
Colombia	23
Comoros	1
Congo	3
CostaRica	3
Democratic Republic of the Congo	14
Denmark	1
Ecuador	2
Eswatini	1
Ethiopia	10
EU	1

Country	# Active D4Ag Solutions
France	6
Germany	8
Gernamy	1
Ghana	64
Global	2
Guinea	2
India	248
Indonesia	32
Israel	1
Italy	3
IvoryCoast	4
Kenya	115
Luxembourg	1
Madagascar	2
Malawi	8
Malaysia	10
Mali	7
Mauritius	5
Mexico	19
Mozambique	3
Myanmar	6
Namibia	4
Nepal	5
Netherlands	17
Nicaragua	2

Country	# Active D4Ag Solutions
Niger	2
Nigeria	162
Norway	2
Pakistan	11
Paraguay	1
Peru	3
Philippines	8
Rwanda	15
Senegal	17
SierraLeone	4
Singapore	11
Somalia	4
South Africa	43
SriLanka	5

Country	# Active D4Ag Solutions
Switzerland	5
Tanzania	24
Thailand	5
The Netherlands	1
Togo	2
Trinidad & Tobago	1
Tunisia	1
Uganda	52
UK	7
United States	10
USA	32
Vietnam	11
Zambia	17
Zimbabwe	14

Grand Total: 1357

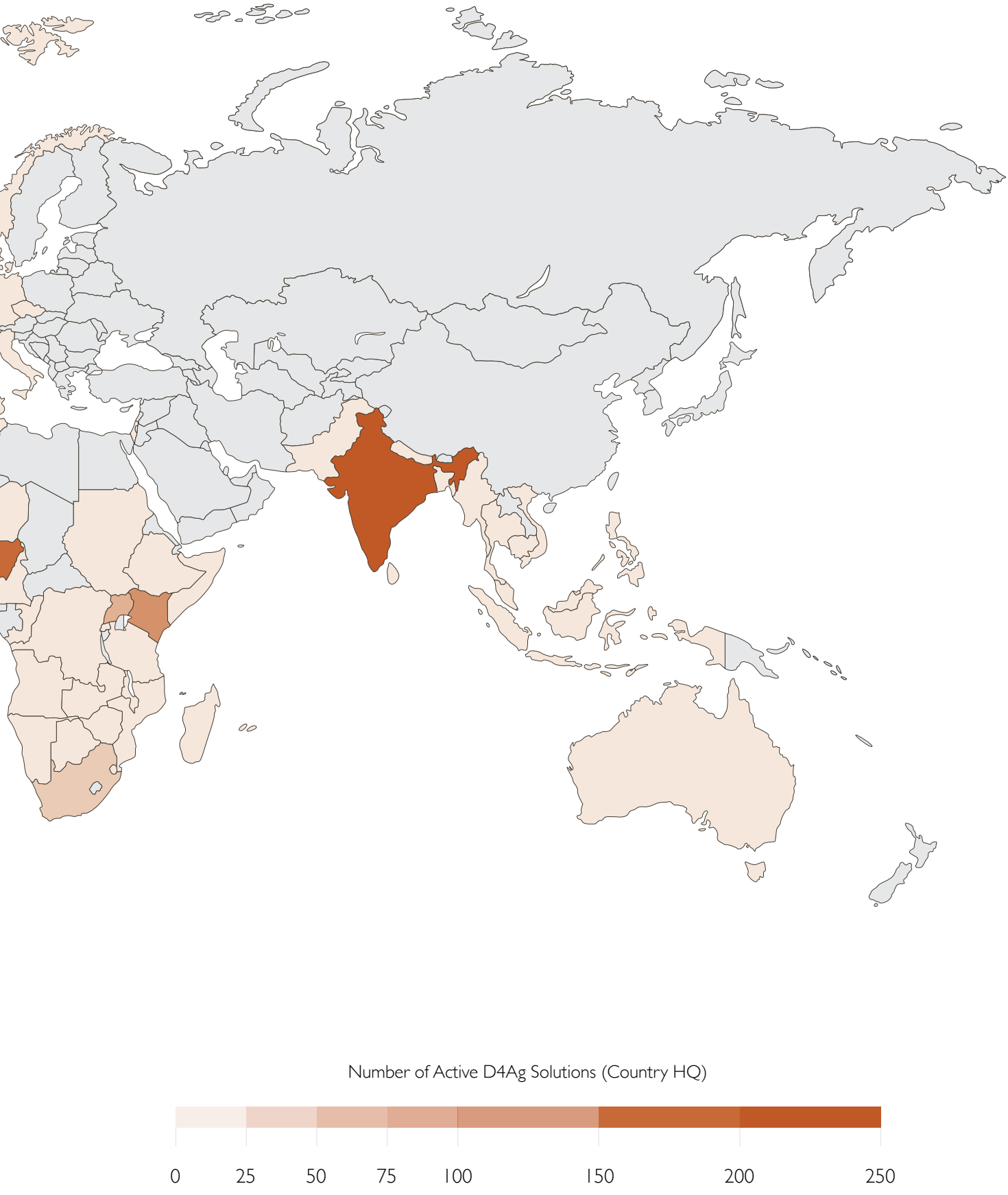


Figure 10. Geographical Map of D4Ag Solutions Expansion — 2022

The number of D4Ag solutions deployed in LMICs has grown seven-fold, showing similar growth patterns but different scales across the globe with little proportional change in the last five years. The peak growth in the number of D4Ag solutions occurred from 2013 to 2018 with a compound annual growth rate (CAGR) of approximately 35%, which has decreased to around 5% from 2020 to 2022. Despite this slowdown, about 45% of D4Ag solutions identified have been started in the last five years.

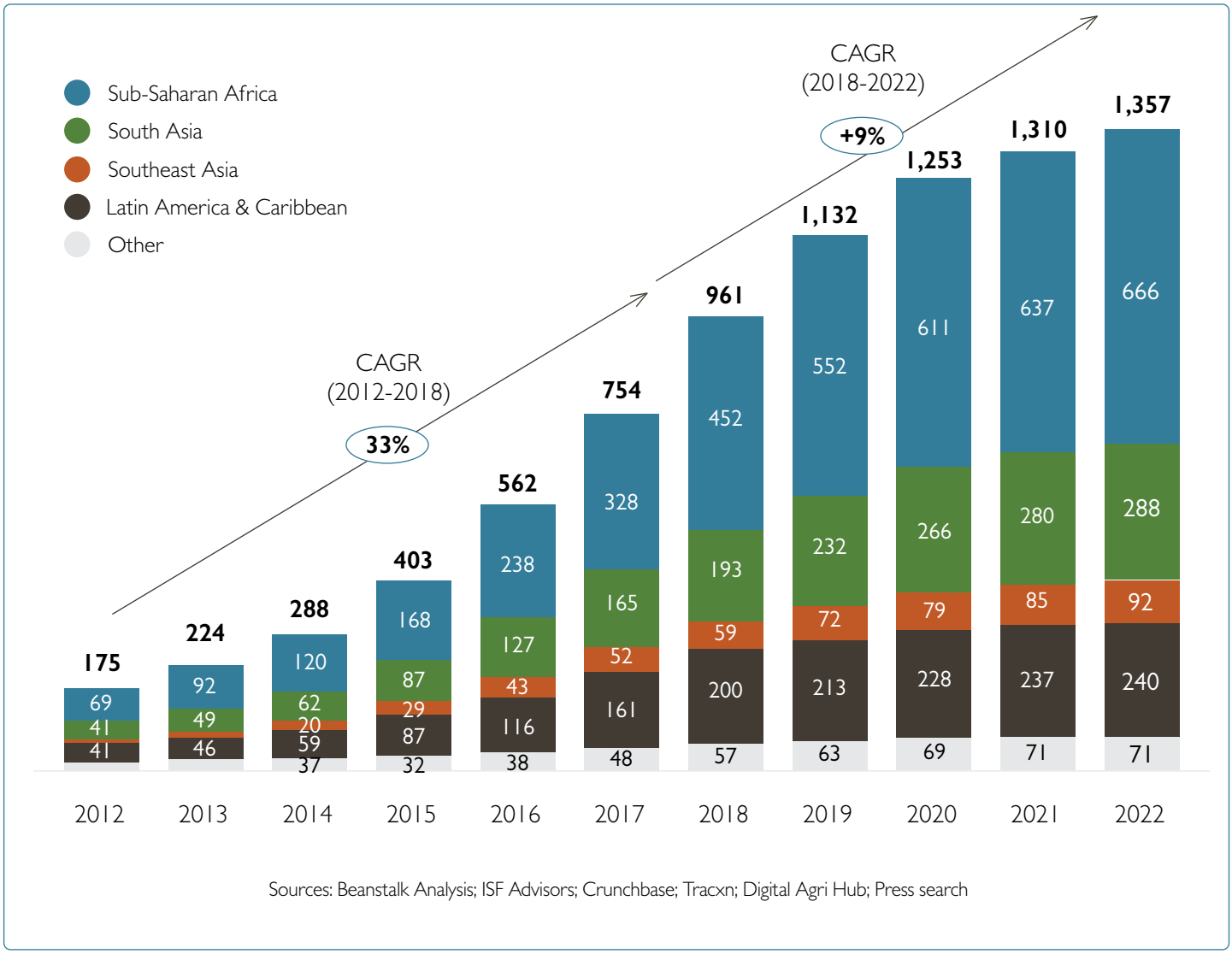


Figure 11. Number of D4Ag solutions (per HQ region), 2012-2022

External factors have played a significant role in this expansion—in particular, a previously favorable lending and investment environment before a recent global downturn. On the other hand, **we have identified at least 130 D4Ag solution providers that have become inactive in the past five years**, representing what would have been around 10% of identified D4Ag solution providers today. This is likely an undercount due to the lack of visibility, especially for bootstrapped founders. Several factors have challenged the viability of D4Ag solution providers over the years, as exemplified by a few notable collapses, two of which are illustrated in Figure 12.

TaniHub

TaniHub Facing Difficulties

TaniHub was an Indonesian D4Ag startup founded in 2015. The company offered four key services: TaniHub, an e-commerce platform to connect farmers with businesses; TaniFund, a crowd lending and financial information platform; TaniFoundation aiming to improve farmers' agricultural and technological literacy; and TaniSupply, a supply chain management platform.

TANIHUB'S ACHIEVEMENTS

As of 2021, TaniHub had supported more than 110,000 farmers, 1139 SMEs, and 350,000 retail customers. According to the founders, 67% of farmers using their services had increased their income by 25%. TaniHub had raised 94.5 million dollars in total across 4 funding rounds. Their lead investors include MDI Ventures, Intudo Ventures, Openspace and Alpha JWC Ventures, and the startups was even publicly appraised by the Indonesian president as a great example of innovation.

TANIHUB'S STRUGGLES

Despite their impact, TaniHub faced several challenges from 2021 to 2022. While they have raised $65 million in their most recent funding round in 2021, TaniHub has changed its CEO, shut down two of their warehouses and had a first round of layoffs. In 2022, TaniHub implemented another round of staff cut due to "efficiency reasons" and ceased operation of their B2C branch. TaniFund, their lending platform, experienced a large number of loan defaults and struggled to pay back their lenders. In March 2022, a petition was filed in Jakarta district court to resolve its loan issues. As of June 2023, the Financial Services Authority of Indonesia issued the last warning letter and is preparing to start the process of revoking TaniHub's operational licence.

wefarm

Shutdown of Wefarm in 2022

Wefarm was a Kenyan D4Ag startup founded in 2015 and subsequently closed down in 2022. The company provided market linkage and advisory services to smallholder farmers, offering digital network that allow farmers to connect and share information via SMS and online. They targeted East Africa market including Kenya, Uganda and Tanzania.

WEFARM'S ACHIEVEMENTS

Wefarm self-identified as the world's largest knowledge network and marketplace for smallholder farmer. They have reached 3.5 million users by 2022, raised $35m in venture capital and hired 120 employees. They have won several awards including Google's Impact Challenge Award, TechCrunch's Europas-Tech for Good Award, and the European Union Commission's Ideas from Europe prize. Their investors included AgFunder, True Ventures, Octopus Ventures and more.

WEFARM SHOP

Wefarm Shop was an application developed by Wefarm to help farmers purchase agricultural products online and share reviews with each other. The marketplace generated $29,000,000 in sales by 2021 and was one of the company's top ventures for income generation.

WEFARM SHUTDOWN

Wefarm Shop was forced to close in 2022 due to "unfavorable market conditions" which made scaling up the business difficult. Wefarm also shut down shortly after. Wefarm's technology platform was brought back by Project Direct, a farmer-owned organization where Wefarm originally started as a project in 2010.

Technology startups in Africa generally face difficult market conditions including low consumer spending power, poor infrastructure and unstable political environment. In the same year, 6 Kenyan technology startups including Wefarm closed in succession within four months for other reasons including shortage of funds.

Figure 12. TaniHub and WeFarm Struggles

Notwithstanding, about **82%+ of identified D4Ag solutions are driven by AgTech startups, a rise from 75% five years ago**. The market has seen increased activity from a range of actors including NGOs, mobile network operators (MNOs) and telecom service providers, financial institutions, governments, and corporate agribusinesses.

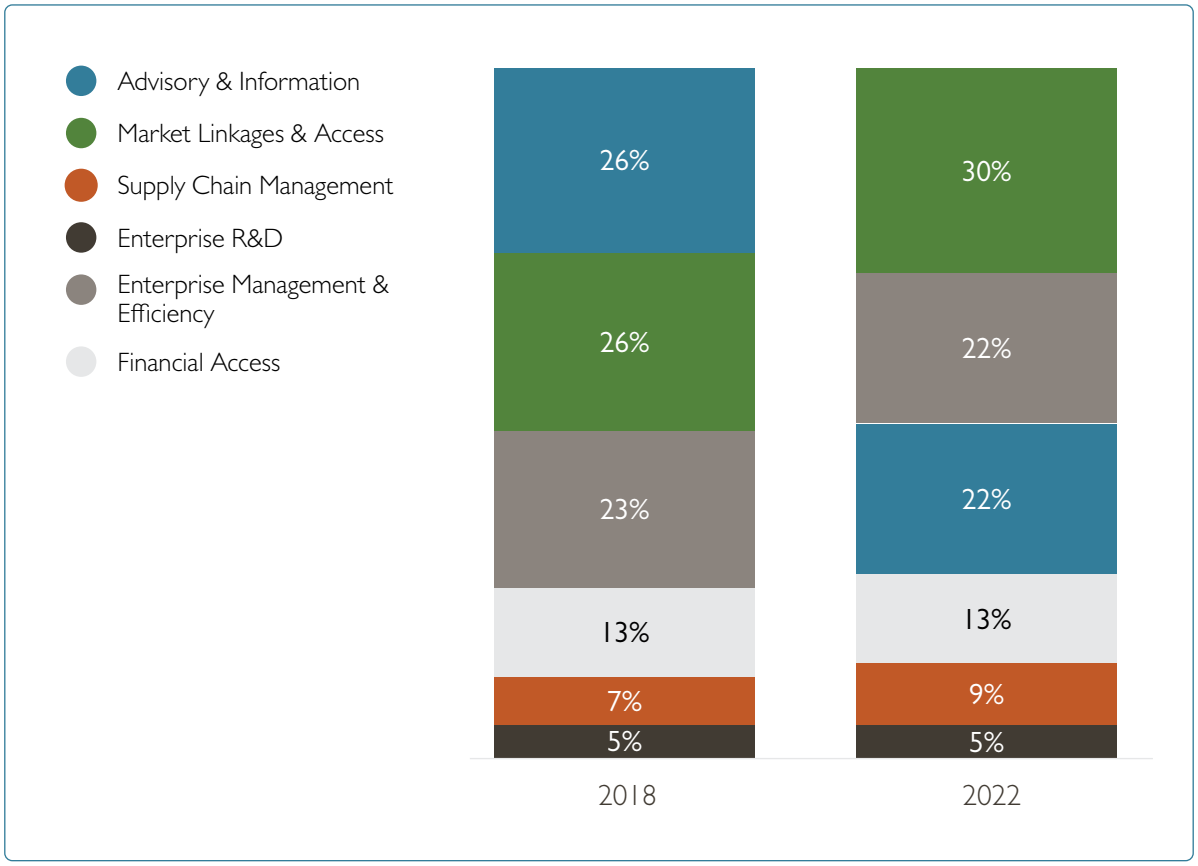


Figure 13. Current and Historical Mix of Use Cases Across D4Ag Solutions (% Of Total)

Since 2018, both "Market Linkages" and "Enterprise Management" have surpassed "Advisory Services" to emerge as the predominant use cases. This transformation may be attributed to the potential attractiveness of Market Linkages to investors, coupled with the promising prospects of commercial viability. The alignment with current market demands and the ability to foster direct connections within the agricultural value chain could be driving this newfound prominence, reflecting an evolving focus and strategy among stakeholders.

As enabling environments and ecosystems have grown and matured, we have observed broader shifts in operating models and shapes of D4Ag solutions. There has been an evolution from "point source" to "networked" solutions, especially in more "mature" D4Ag ecosystems like Brazil and India. The model of digitally enabled "products" to solve pointed challenges for particular locales has, to some extent, been displaced by multifaceted and multiuse case solutions leveraging APIs and digital connectivity more broadly to scale offerings and entry points. **Among the >1,300 D4Ag solutions we have identified in LMICs, more than 40% of them are already offering multiple use cases; however, the picture differs significantly across different use cases.**

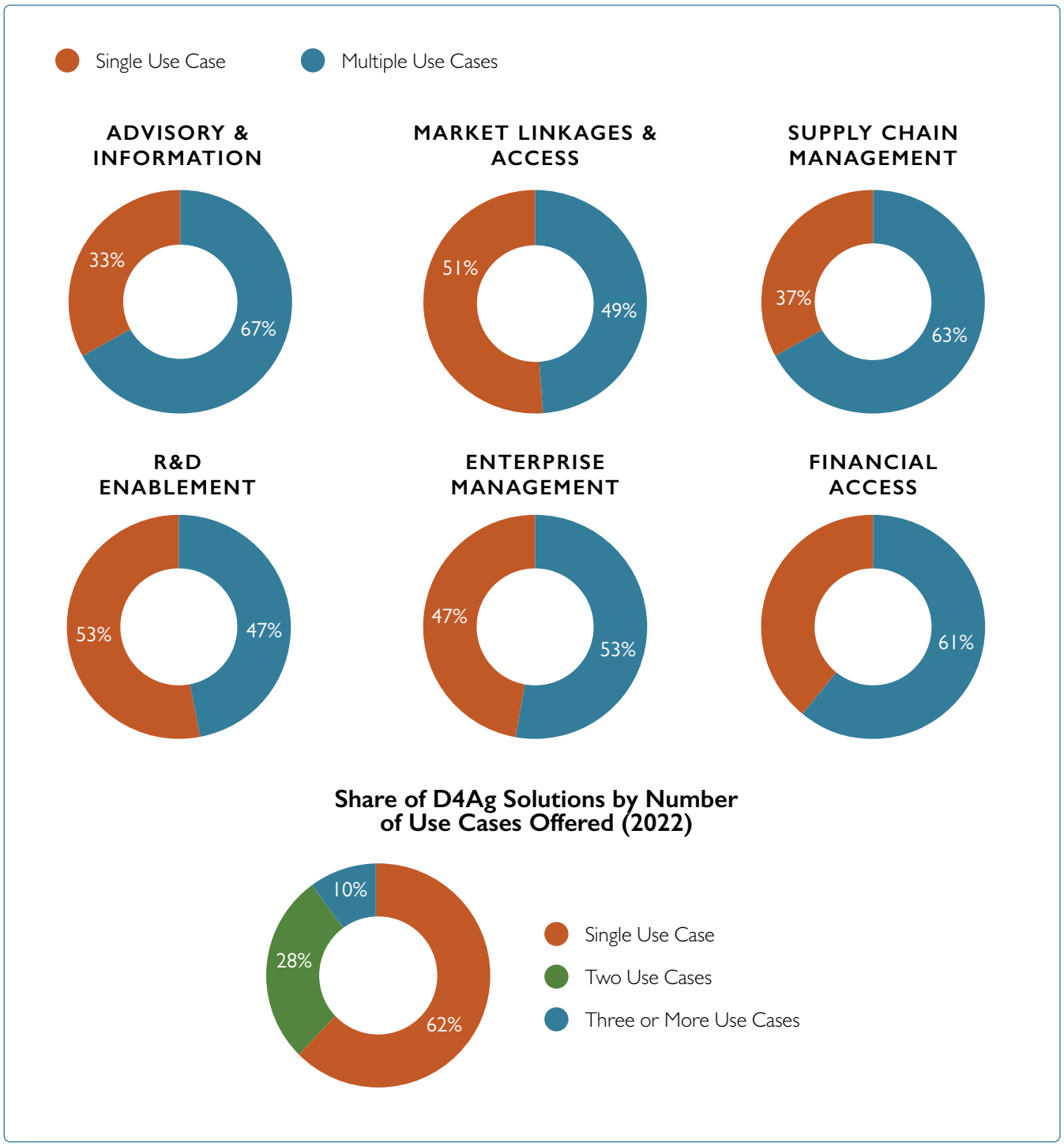


Figure 14. Number of Use Cases Offered by D4Ag Innovators

The bundling of D4Ag use cases is driven both by "opportunity" and "need": The former is given greater density of high-quality solution providers and expanded penetration of mobile connectivity. The latter is due to challenges in unit economics of scaling one-dimensional solutions such as higher cost of acquisition and lower cost of retention. For instance, farmers often only have two to three cycles per year where they "transact"—buying inputs or selling outputs—so the integration of advisory and other solutions may present other opportunities for monetization but are more commonly recognized as delivering "stickiness" and lifting the level of engagement.

Source: Feed the Future Flickr. Photo credit: Miles Sedgwick, Rana Labs

There has been a parallel shift away, in a macro view, from pure play "Advisory & Information" or "Enterprise Management & Efficiency" to also offering "Market Linkages" services. The former model has its roots in and is more established in the USA and Western Europe, where there is greater willingness to pay, more established pathways to embed cost (such as in inputs and financing), and potentially greater value and agency from unique insights. However, we are observing pivots, even from established advisory operators, to participating in a "transaction" generating options for revenue participation. There are definitely some exceptions where barriers to information are particularly severe, like in frontier markets where market systems and formal knowledge-sharing systems may be more tenuous.

Moreover, we have observed an ongoing shift toward AgriFinTech models with 61% of innovators there offering multiple services,

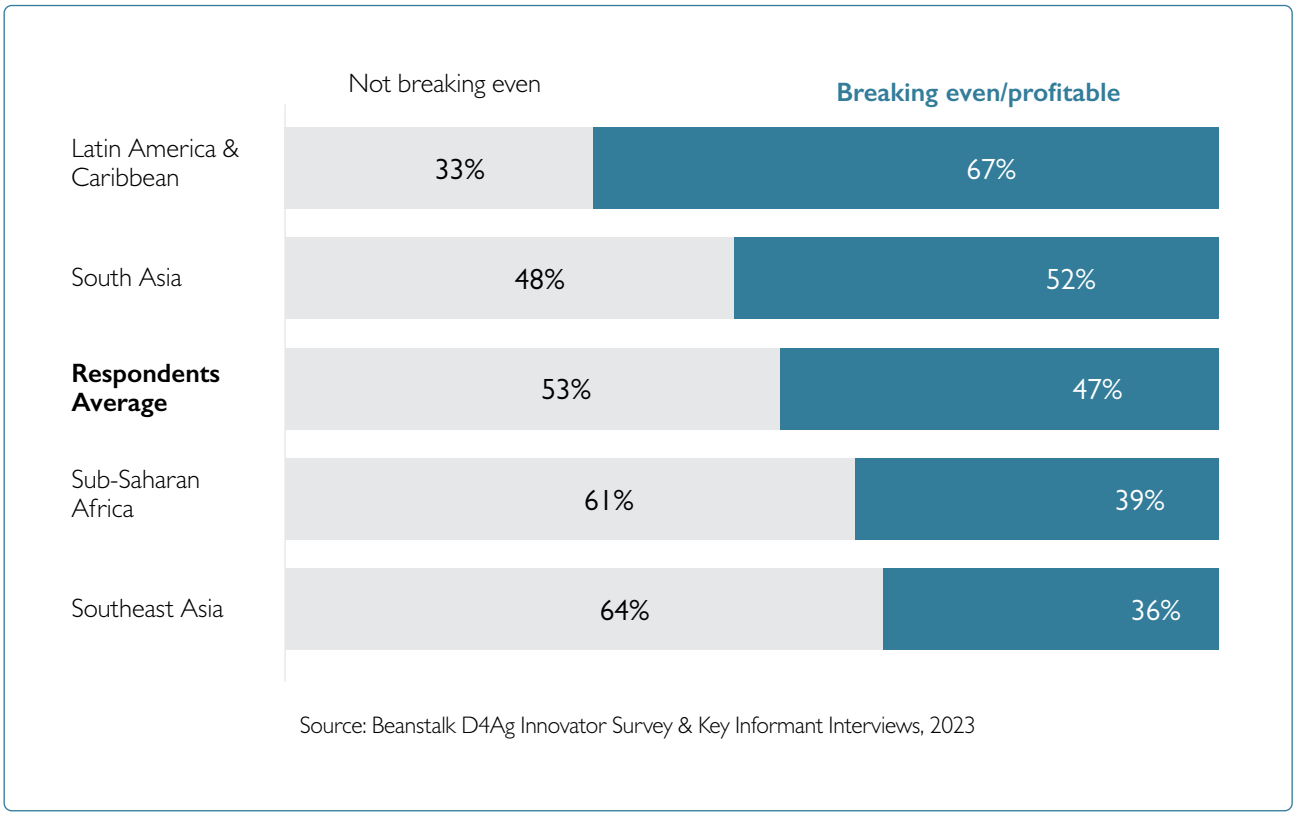


Figure 15. Profitability of Surveyed D4Ag Innovators, Per Region (% of innovators surveyed (n=75))

using Financial Access as entry points to a broader range of use cases while leveraging other service offerings as a differentiated value-add. This is likely to be due to a range of reasons including the depth of government investment in financial inclusion, the reduction of transaction costs and bureaucracy in recent years, increasing comfort with digital payments, and general familiarity and perceived scalability. However, the problem of access to capital for farmers is still acute in most LMICs. For instance, in India, a more advanced D4Ag ecosystem has made great strides in financial inclusion; but still, over two-thirds of smallholder farmers have never had any access to institutional capital. Banks and financial service providers are playing an increasingly active role in the D4Ag ecosystem, benefiting through increased book value, lower non-performing loans (NPLs), reduced transaction costs, and more.

The D4Ag sector, initially largely donor-dependent, has shown a marked evolution. A considerable proportion of D4Ag solutions have demonstrated enough traction, revenue, and income to maintain viability. While there is some bias in our survey, **almost half of the innovators we interviewed or surveyed claim to have surpassed breakeven and are operating profitably**. Interestingly, the picture differs drastically across the regions: Among our Latin American interviewees, 67% claimed that they are already breaking even, while this figure drops to below 40% in sub-Saharan Africa and Southeast Asia. Conversely, some providers have attained significant scale by serving donor-funded projects, such as Viamo and Digital Green, placing them in potentially precarious positions.

D4AG REACH AND ADOPTION ACROSS LMICS

The following section intends to unpack the current reach and adoption of D4Ag solutions in LMICs. Understanding the reach and adoption of D4Ag in LMICs today is fundamental to evaluating its impact, or lack thereof, on lives and livelihoods in the agricultural sector. Despite the proliferation of studies exploring the evolution of D4Ag in LMICs and across the globe, there have been very few public efforts to quantify uptake of D4Ag solutions in a meaningful way. Mainly, the existing reports rely on more ready (and surely more accurately estimable) proxy indicators, such as rates of smartphone ownership, internet connectivity, and/or mobile money penetration. More nuanced, fit-for-purpose insights into adoption levels and patterns across regions and sub-populations can guide better strategies, investments, and innovation across the sector.

One of the main reasons that adoption data is so sparsely collected and publicly disseminated to date may be because the concept of "adoption" is so complicated in itself. There is not a universally agreed-upon definition of "adoption," especially when discussing impactful, meaningful, or active use. We list below but a few of the complexities that make an industry-wide adoption specific difficult to manage.

End-user diversity: First, the spectrum of target users is vast, ranging from small-scale producers to agro-dealers and financial service providers. Our research involved surveys and interviews of innovators in the D4Ag sector, and based on the responses, we identified four primary categories of users for D4Ag solutions. Most solutions are designed to target one or two user groups, predominantly smallholder farmers and value chain intermediaries.

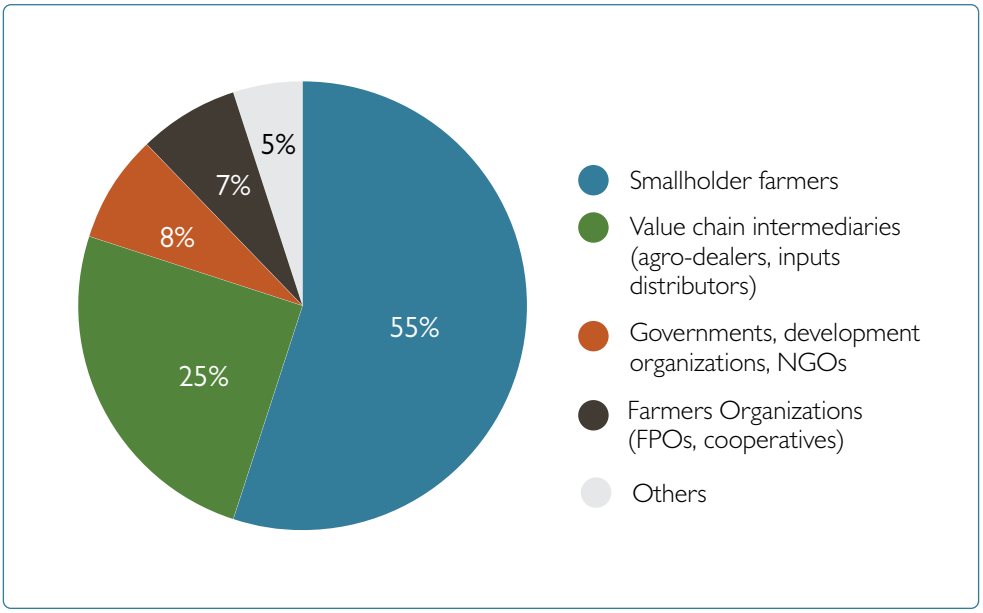


Figure 16. Most Common User Groups of D4Ag Solutions

Metrics used: The metrics used to measure the scale of adoption also vary greatly, including aspects besides just number of people, but also things such as acreage covered, transaction values on the platforms, or volumes handled. Moreover, when talking about adoption of D4Ag in other value chains, besides cropping, we have commonly seen metrics like number of animals for livestock-oriented tools, or number of ponds and fishing vehicles for the solutions targeting aquaculture and fisheries sector.

Level of engagement: Additionally, there is no clear definition of what constitutes an "active" user. Our research indicated that many solutions define an "active" user predominantly by the frequency of service usage. But this frequency is not consistent across tools, suggesting a lack of uniformity in defining active engagement, as

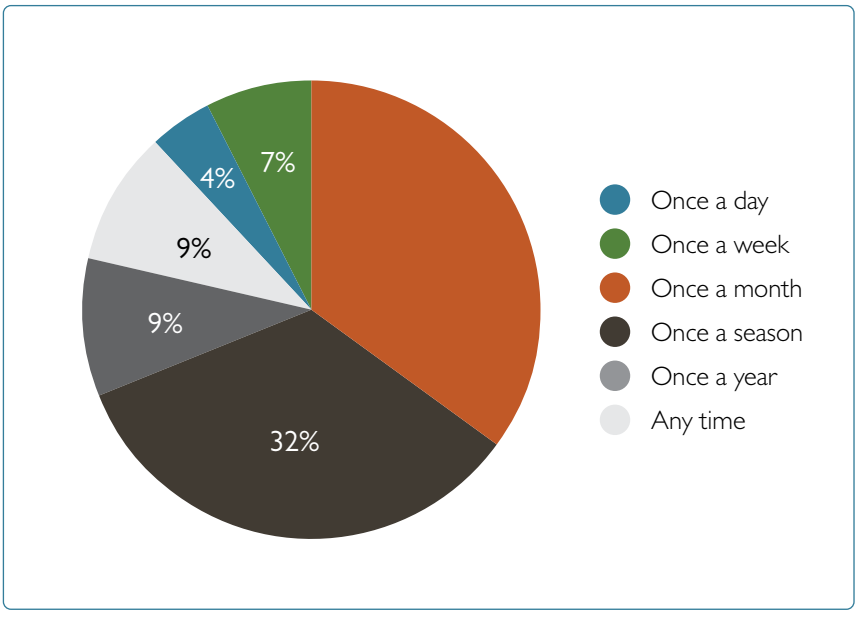
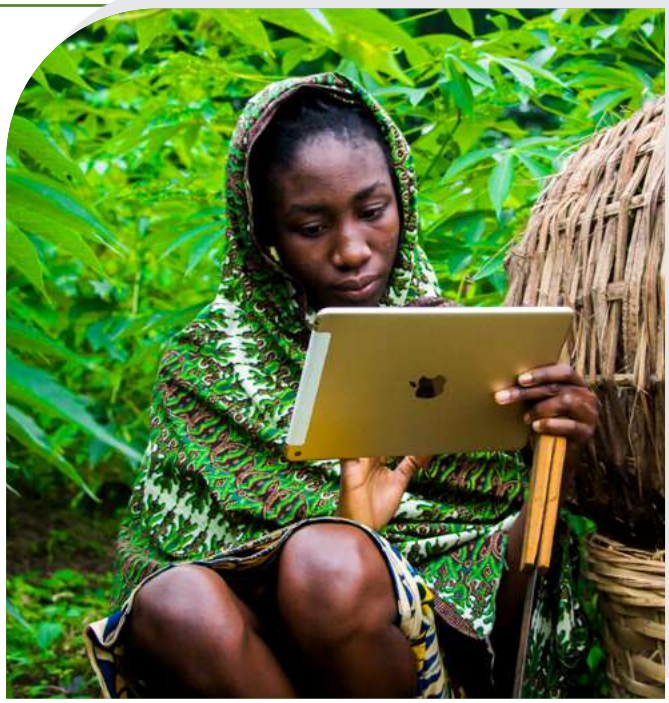


Figure 17. How Different D4Ag Innovators Define Active Users

there is no distinct correlation with the specific use cases. This variability could be due to the inherent flexibility of most D4Ag tools. For example, a digital farming advisory service can be accessed as much or as little as the farmer requires advice or recommendations.

Most services use month and season as the time unit for measuring frequency of usage, respectively used by 33% and 32% solutions surveyed. Given that these solutions mostly target smallholder farmers, this suggests a relatively low expectation of technology use by smallholder farmers across different types of solutions. For the purposes of this report, we have adopted a definition of "active" users from CTA's 2019 report.



Source: Feed the Future Flickr. Photo credit: Miles Sedgwick, Rana Labs

Registered Users	The number of registered accounts in the database
Engaged Users	Those users who know how to use the solution and have done so at least once monthly in the past year
Active Users	The percentage of accounts used regularly enough for users to feel the full benefit of the solution

Figure 18. Definition of D4Ag User Types

Our approach to approximating adoption has been focused on estimating the level of "active" usership of these tailored D4Ag tools. In our study, we denote "active users" as those who use the solution regularly enough for them to feel the full benefit of the solution, however often it might be.[3] A registered user may or may not be an active user, and it is vital to differentiate between someone simply registered and someone actively benefiting from the tool, when considering the tangible impact on farmers' lives.

Surely, hedging on a single, all-encompassing estimate for adoption is not practical or reflective of reality. D4Ag solutions are incredibly varied in their levels of sophistication, target user groups, expectations and requirements of active use, therefore, they all display different rates of penetration, even within the same region. For clarity, in this report, our focus on D4Ag adoption zeroes in on specialized, fit-for-purpose D4Ag solutions. We intentionally exclude generalized technologies that might be used in agriculture but are not specifically crafted for it, such as social media or mobile money. Our aim is to provide a more nuanced perspective on the real uptake of digital agriculture tools and their impact on the lives of smallholder farmers in LMICs that is not overly optimistic due to an overemphasis on the adoption of adjacent technologies.

We advocate vehemently for a more structured and systematic approach to measurement of meaningful adoption of D4Ag solutions in the future. Standardizing measurements, particularly in defining terms like "engaged" or "active" users, are vital. Moreover, regular and broad-based data collection will be instrumental in drawing consistent comparisons in the future. Such efforts will aid in pinpointing opportunities and bottlenecks more effectively, enabling more informed decisions and strategies in the D4Ag domain.

Current D4Ag Adoption Numbers in LMICs

The adoption of D4Ag tools has been slow across the globe, and research into the uptake rates at a regional level has been severely lacking. According to CGIAR, globally, more than 150 million smallholder farmers in developing countries (25%) did not have access to any digital services in 2021.[4] In Southeast Asia, it is found that less than 10% of agriculture SMEs use basic farming apps that provide advisory, enterprise management, and market linkage services.[5] In sub-Saharan Africa, "The Digitalisation of African Agriculture Report 2018–2019" found that in 2018, only 10% to 13% of smallholder farmers in the region had registered for some kind of D4Ag solutions, and just 15% to 30% of these accounts were active.

[3] The Digitalisation of African Agriculture Report 2018–2019, CTA, 2019

[4] Stephenson J, Chellew T, von Köckritz L, Rose A, Dinesh D. 2021. Digital agriculture to enable adaptation: A supplement to the UNFCCC NAP Technical Guidelines. CCAFS Working Paper no. 372. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

[5] Advancing Towards ASEAN Digital Integration: Empowering SMEs to Build ASEAN's Digital Future, Bain & Company

Country	Example application	**Kenya** (Sub-Saharan Africa)	**Mexico** (Latin America and the Caribbean)	**India** (South Asia)	**Indonesia** (Southeast Asia)
INTERNET PENETRATION[1] (% of total population)	Farmer checks the weather forecast using community computer to make decision on when to plant seeds	42%	79%	47%	74%
SOCIAL MEDIA PENETRATION[1] (% of total population)	Producer association has a WhatsApp group to communicate real-time prices and share intel on trade experiences with credit providers	21%	73%	33%	69%
SMARTPHONE OWNERSHIP[1] (% of total population)	Farmer takes picture of pest issue in their crop field and sends to peers who help them identify the pest and treatment strategies	33%	57%	35%	43%
MOBILE MONEY PENETRATION[2] (% of total population)	Farmers in Bangladesh use a mobile app to purchase quality seed from agri-input retailer	63% *Regional	9% *Regional	18% *Regional	15% *Regional
PENETRATION OF SPECIALIZED, FOR-PURPOSE D4AG TOOLS (% of farmers)[3]	Farmer uses IoT sensors and farm management mobile app to monitor condition of soil	13%	20%	13%	8%

1. GSMA: The State of Mobile Internet Connectivity Report (2022)
2. GSMA: The State of the Industry Report on Mobile Money (2023). Regional mobile money penetration was used in absence of country level data.
3. Estimates used are based on available regional and country level penetration data and adjusted for relative market maturity

Figure 19. Adoption Rates of Various Internet and Mobile Technologies

The table above includes the latest available data on internet penetration, smartphone ownership, and use of social media and mobile payments in selected LMICs. These numbers can provide a baseline estimation of the number of potential users of D4Ag technologies, offering a context in which to gauge the reach and impact of these for-purpose solutions.

The scarcity of on-the-ground data makes it challenging to precisely estimate the current penetration levels in LMICs, but based on existing data points, **we estimate that no more than 10% of potential end users[6] in low- and middle-income countries are actively using D4Ag tools, with the total number of active users amounting to ~50.1 million people.** In the leading D4Ag markets like Kenya, Brazil, India, and Nigeria, the adoption rates are relatively higher, ranging from 13% to 20%. Emerging landscapes such as Indonesia and Pakistan present a middle ground with adoption figures at about 6% to 8%. In nascent D4Ag ecosystems, where digital technologies in agriculture are still in their infancy, the adoption is likely to be below 3% to 4%.

	Sub-Saharan Africa	South Asia	Southeast Asia	Latin America and the Caribbean
No. of agri workers (USDA ERS)	202,769,129	252,831,323	96,671,241	38,798,551
Estimated proportion of active users (% of people employed in agriculture)	5%	10%	6%	17%
Estimated # of active users	10,876,687	26,498,311	6,152,794	6,621,297
Estimated # smallholder farmers [7]	~ 190 million [8]	~ 180 million [9]	~ 100 million [10]	~ 15 million [11]

Table 2. Current State of Reach and Adoption in LMICs

[6] For the modeling purposes, we have used the Ag Labor estimates from US Department of Agriculture's Economic Research Service (ERS), as a proxy for estimating the number of potential end users in each country, due to the absence of definitive smallholder farmer figures at the country level. While this might not mirror the exact user base, it provides a foundational estimate. For a detailed breakdown of our methodology, see Appendix 1.

[7] There is no universal definition of the term 'smallholder farmer', but for the purposes of this report we define smallholder farmers as individuals who produce crops or livestock on two or fewer hectares of land.

[8] The Digitalisation of African Agriculture Report 2018–2019 (cgiar.org)

[9] Based on available country-level estimates (Solidaridad India, IFAD Pakistan, iFarmer Bangladesh, UNEP Nepal, The World Ban Sri Lanka)

[10] Unlocking Smallholder Finance for Sustainable Agriculture in Southeast Asia - Climate Focus

[11] OECD-FAO Agricultural Outlook 2019-2028

Photo credit: WRMS

Clarifying the Difference: D4Ag Adoption Model vs. that of the CTA 2019 Report

Readers familiar with the CTA 2019 report may notice that our numbers at first sight present a divergence, specifically showing lower adoption numbers (5% for SSA), than the 13% penetration estimated five years ago. We aim to shed light on the differences in methodology and interpretation which result in this discrepancy:

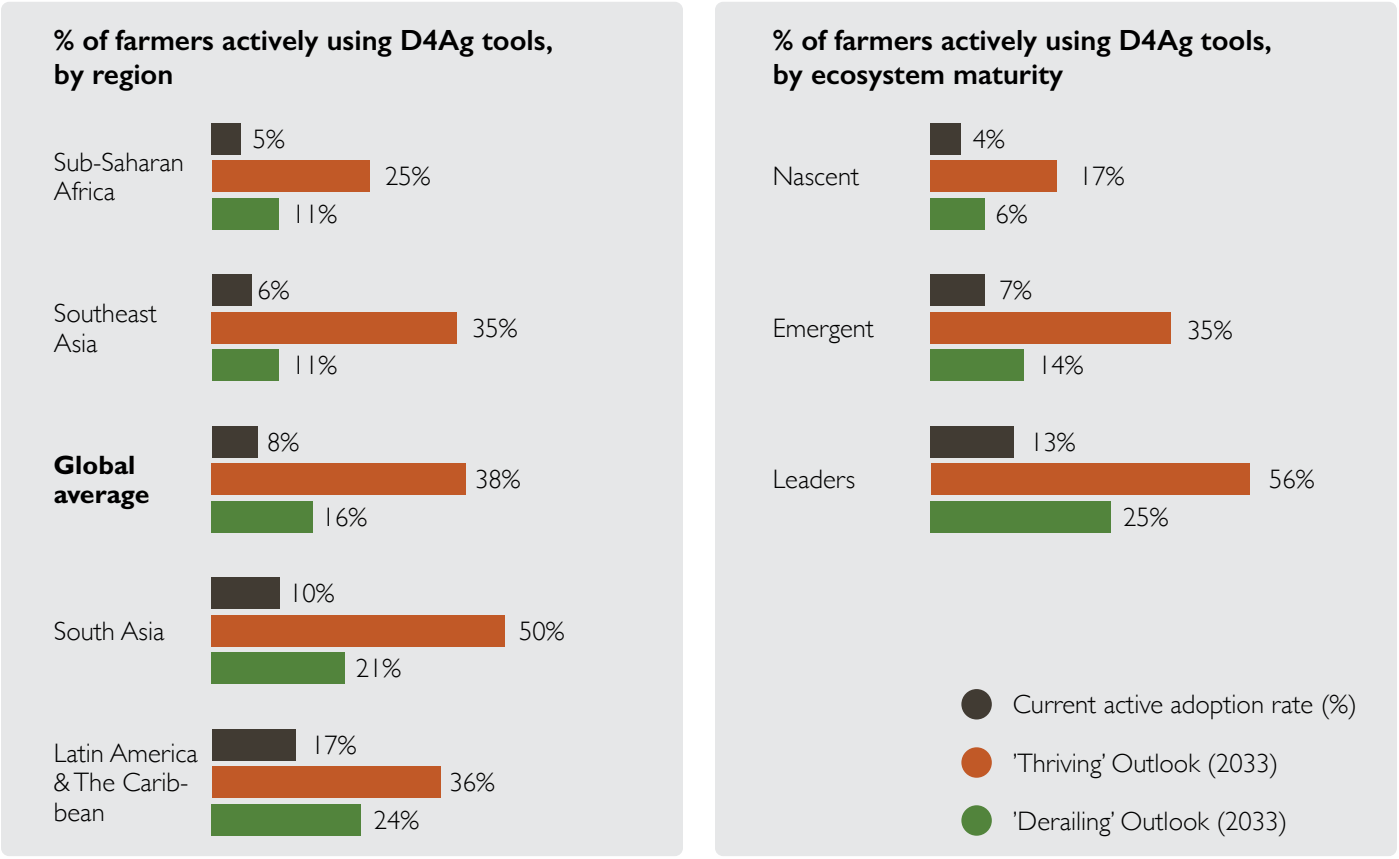
Active vs. Registered Users: As we already mentioned, our focus centers on "active users", while the commonly referenced 13% adoption estimate from the CTA work refers to simply the number of registered accounts (33 million) in the database of all D4Ag solutions identified back then. The authors acknowledge that not all of the accounts (but only 15-30%) were actively using the solutions, and estimate that **active users adoption was no more than 4%**. It means that according to our estimates, **the number of active users in Sub-Saharan Africa has increased by 25% since 2018.**

User Duplication Assumptions: Our approach aims to assess the number of unique, active users of a given D4Ag tool, attempting to sidestep the challenge of user duplication across platforms. The CTA report, conversely, totals registered users across all D4Ag solutions, based on an assumption of 0% duplication for the 13% adoption figure. We believe that there might be an underestimation of overlap, especially as number of tools available for the farmers continue to soar.

Basis for Estimations: The space of D4Ag adoption remains one wherein comprehensive data is scarce. Our model leans on specific data points from existing research papers that offer insights into regional D4Ag adoption. The CTA report uses a different methodology, drawing from their dataset of 390 active solutions and the number of registered accounts for each of them. Besides, the baseline number of 250 million potential users in the CTA report differs from ours, as we do not include the number of pastoralists in our model.

Overall, neither model claims complete accuracy but both do offer directional insights into the state of D4Ag adoption in the region. In essence, while the numbers might differ, the overarching aim remains the same: to assess and foster the impact of D4Ag tools on their end-users. We encourage readers to understand the nuances in methodologies and appreciate the broader narrative of D4Ag's transformative potential in the agricultural sector. Please, refer to the Appendix 1 for further details on our methodology.

Figure 20. Clarifying the Difference: Beanstalk D4Ag Adoption Model vs. that of the CTA 2019 Report.



Note: Available data was extremely limited. Available country data was extrapolated to represent the entire progression status per region. Where data was not available, the 2016 Digital Adoption Index (DAI) was utilized to estimate current adoption levels. The thriving scenario was projected by using the internet adoption curves of each country with an adjustment factor. Relative to internet adoption, the following lag was assumed for D4Ag adoption: Leaders – 10-year lag, Emergent – 12-year lag, Nascent – 15-year lag.
Source: Various, World Bank World Development Indicators (Individuals using the Internet (% of population)), Beanstalk analysis

Figure 21. Estimated rates of D4Ag adoption across regions and D4Ag ecosystem maturity levels

While systematic data on overall market penetration outside of sub-Saharan Africa is quite scarce, individual D4Ag solutions are making some substantial strides. In fact, we have identified 96 D4Ag solutions boasting a minimum of 50,000 users, and 32 solutions that reached the one million user mark in LMICs. Despite signaling about the growth of the sector, even the "giants" like Indian **eNam** and **BigHaat** currently do not reach more than 15% of the smallholders in the country. We have also identified the top-10 solutions in each of the regions, please refer to the Appendix 4 for further details.

The majority of D4Ag innovators interviewed and surveyed report to have between 1,000 and 500,000 users, with a median number of registered users per solution standing at 60,000 smallholder farmers. However, we do acknowledge some bias in our interview pool, and real numbers are most likely lower due to a large number of nascent and small-scale solutions that were not included in our pool.

Enablers and barriers to D4Ag solution uptake have been extensively investigated, revealing several patterns. The "Agriculture in the Digital Age"[12] research-to-evidence program—through a broad review of 315 quality studies on D4Ag uptake—identified 74 use facilitators and barriers across four dimensions: performance expectancy, social influence, facilitating conditions, and effort expectancy.

[12] Agriculture in the Digital Age report, 2023
[13] For some solutions (such as Viamo 3-2-1), the number of users includes not only farmers or stakeholders in the agricultural value chains, but broader population groups.

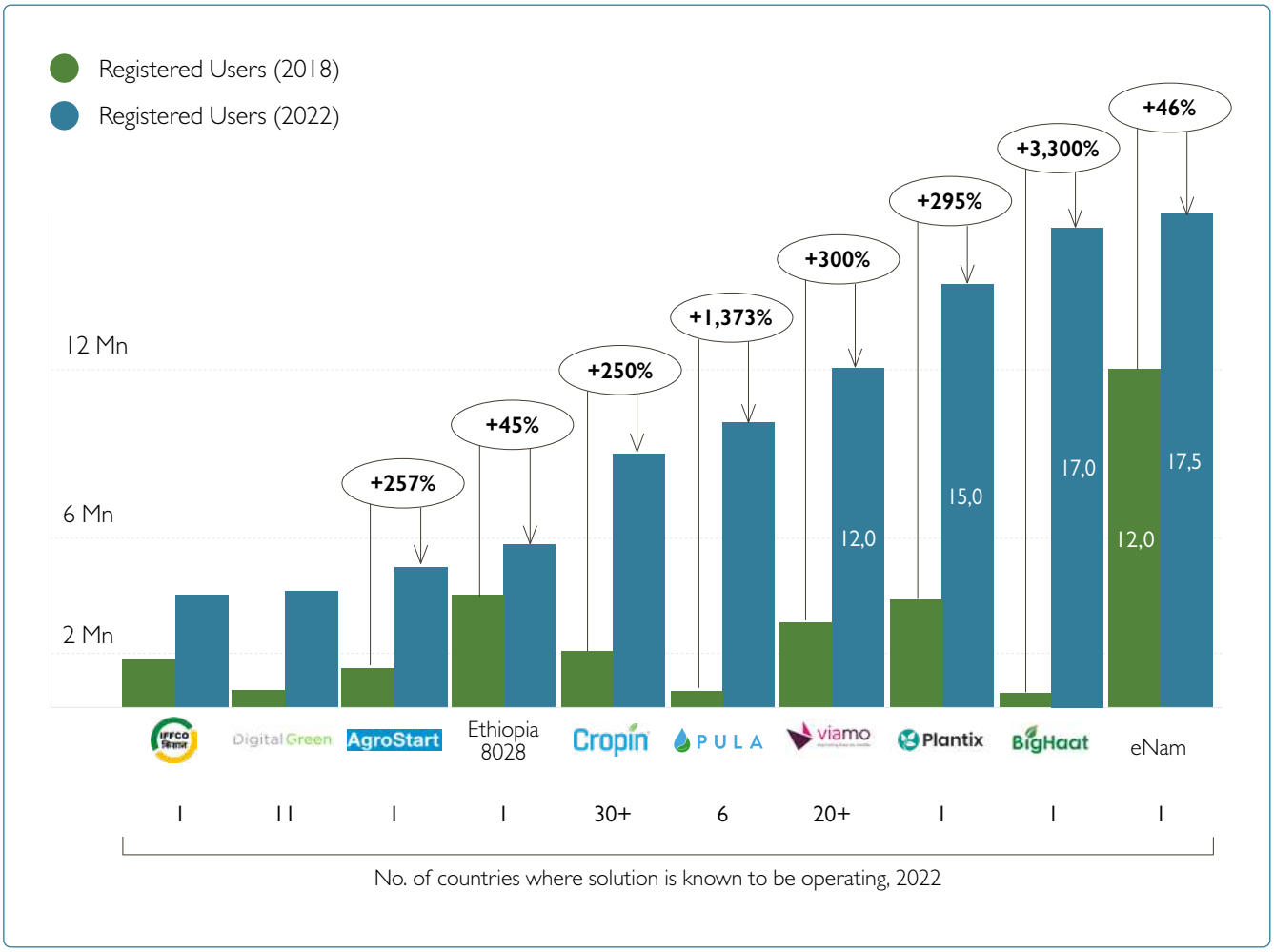


Figure 22. Registered Users of Top 10 D4Ag Solution Providers. Million Users, 2018 Vs. 2022, Global[13]

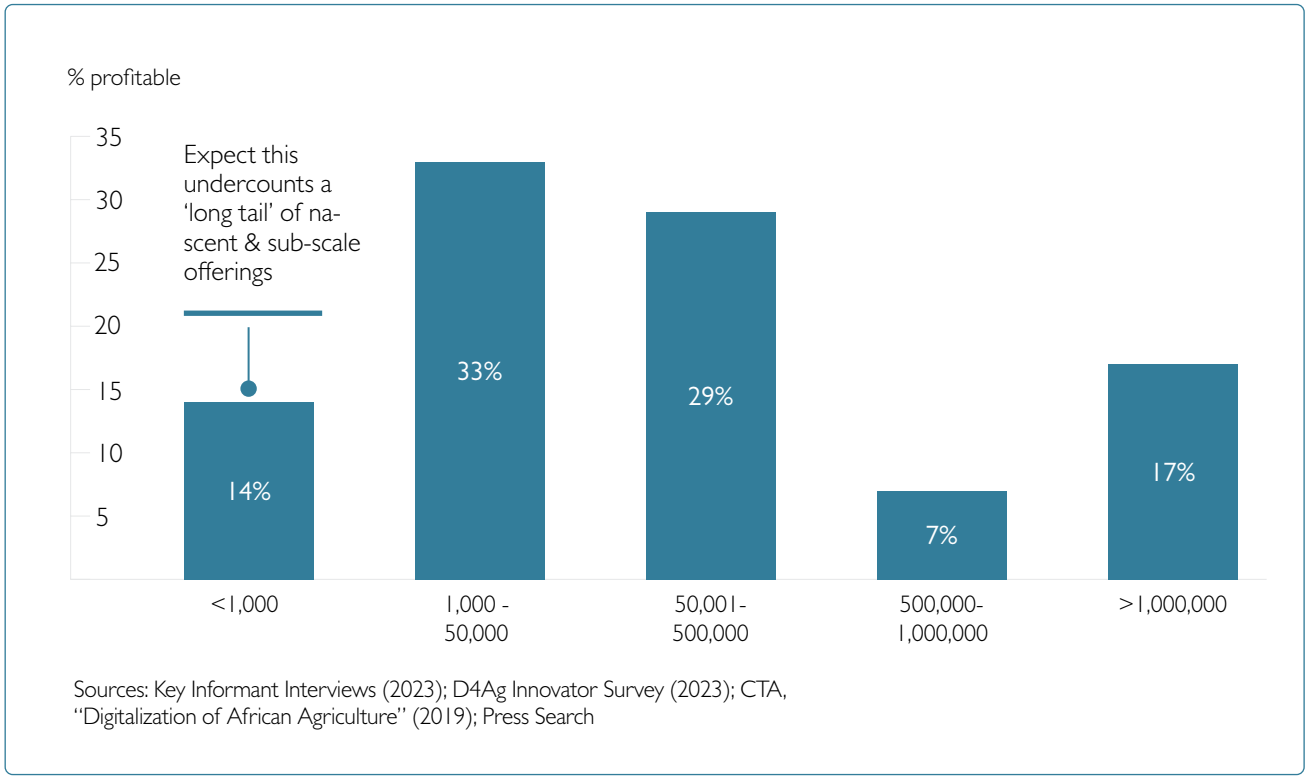


Figure 22. Share of D4Ag Solutions by number of registered users 2022, Global (n=180)

Source: Agriculture in the Digital Age

Figure 23. D4Ag Use Facilitators and Barriers. Source: Agriculture in the Digital Age

Critical barriers to D4Ag adoption have been extensively studied and include aspects like device access, mobile network availability, and awareness of D4Ag solutions. Other factors that impact adoption include trust, localization, capital access sensitivity, support for discussion, and interactivity.

While our research has largely mirrored these findings, our interviewees have mentioned a few additional barriers to D4Ag adoption in LMICs. These include counteracting a perceived **"digital fatigue"** that stems from the proliferation of digital technologies, particularly among those producers and value chain actors who have had exposure and negative experiences with earlier digital initiatives.

> *"So the biggest challenge commercializing has been the one, of course there is a proliferation of digital technologies in our market, especially in Kenya. And you realize that the target segment has already been exposed to so many applications that have worked or have not worked [for them]. And so, there's already this barrier of entry, let me say a* ***digital fatigue.*** *It sounds contradictory, but we realize that there is a bit of resistance from farmers or even the businesses at the ground [to try new tools], because they have had so many of these tools coming in, and most of them have not worked for them."*
>
> D4Ag Innovator, sub-Saharan Africa

The challenge of **reaching the "last mile"** — that is, cost-effectively identifying, engaging, acquiring, and onboarding end users — also presents a significant obstacle. We do see evidence that partnerships with local organizations, innovative use of existing infrastructure (such as community radio or mobile money agents), and tailored approaches to cater to the specific contexts of these communities (such as solutions that work on basic mobile phones or in local languages) can be effective in addressing this challenge. Surely the role of intermediaries is complex, yet crucial. Approaches such as working with cooperatives, producer organizations, and extension agents offer promise, as do various knowledge brokers and community support models. Developing a scalable, locally embedded, shared resource of intermediary personnel could unlock significant value in the D4Ag sector. In addition, innovative models such as village-level entrepreneurs or "gig economy" models have shown promise in enhancing the reach and impact of D4Ag. For instance, innovators mentioned that "digital village advisors" who provide tech support and training to farmers in their community help significantly improve the uptake and usage of D4Ag solutions. However, they also highlighted the need for adequate training, support, and incentives for these intermediaries to ensure their effectiveness and sustainability.

Intermediary	Pros	Cons	Examples of Models
Farmers Cooperatives/ Organizations (formal/ informal)	High level of trust among members, can disseminate information effectively, can facilitate group training.	May not exist or be strong in all areas; heterogeneity and lack of transparency within organizations may pose challenges.	WFP's **Farm2Go** mobile app connecting farmers to markets and available in Rwanda, Mozambique, and Bangladesh, reaches farmers through tables distributed to heads of local cooperatives. In this way, the program aims to overcome low individual smartphone ownership in these countries.
Extension Agents	Trusted by farmers, understand local farming challenges, can provide training and support.	Their number and reach may be limited, particularly in remote areas. Also, their digital literacy levels can vary. There are little incentives mechanisms for them to engage.	**Digital Green** partners with existing agricultural extension workers in India and Ethiopia to develop the content for the videos, as well as provide training for them on how to use the videos.
Village-Level/ Micro-/ Agro-Entrepreneurs	Understand local contexts, trusted by communities, can provide on-the-ground support.	May require substantial training and support, and ensuring consistent quality of service can be challenging. Often struggle with lack of finance, especially for working capital.	**E-Vuna (Mezzanine)** in Kenya uses a USSD-based interface to engage directly with farmers, while they have also developed a mobile app that is used by their "village-based agents," who are equipped with smartphones that have a mobile application and necessary digital literacy levels to complete the farmer registration on the ground. Many Indian startups (**AgroStar**, **DeHaat**, **Samunnati**) leverage so-called "micro-entrepreneurs" networks for providing both delivery of inputs and other products to farmers as well as collection of their produce for delivery onwards to distributors and other offtakers. **Syngenta Foundation for Sustainable Agriculture** runs one of the largest Agri-Entrepreneurs programs in India, counting more than 10,000 active entrepreneurs serving > 1,000,000 farmers.[14]
Ancillary service providers (mobile money agents, providers of solar irrigation kits, etc.)	They are often widely distributed, even in rural areas, and are a trusted part of the financial system for the smallholders.	Lack of incentives. May require additional training to support D4Ag solutions.	In Kenya, **mShamba** has deployed a unique approach to develop partnerships with other service providers, such as solar irrigation kits or financial services agents, and their products are made accessible to the farmers via mShamba's digital platform. The company has even partnered with boda-boda drivers in the country who jointly provide transport and marketing services.

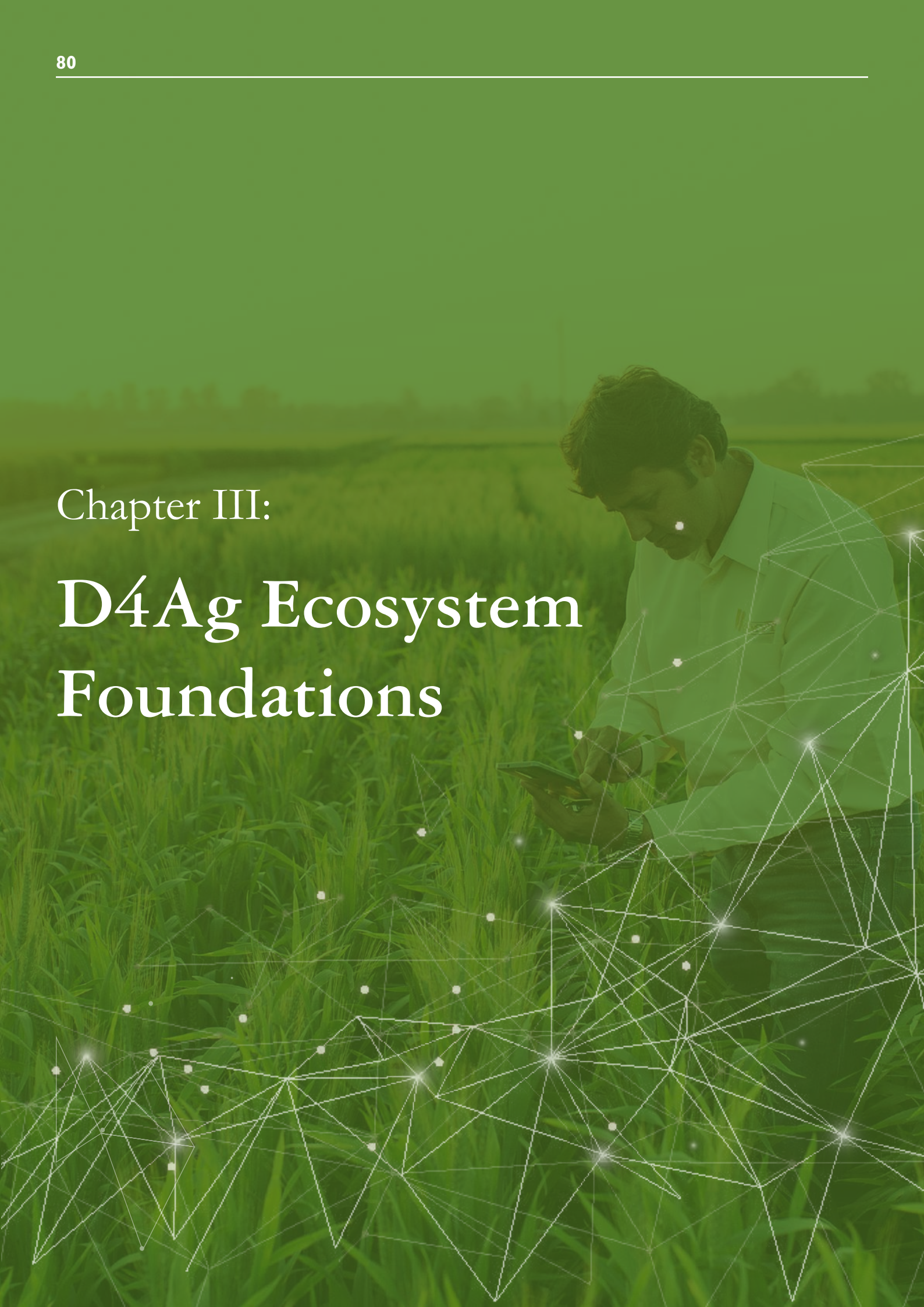
[14] Beanstalk Key Informant Interview, 2022

Intermediary	Pros	Cons	Examples of Models
Agricultural Input Dealers	Have regular contact with farmers, understand their needs, and are often trusted sources of information.	The incentives are not always aligned with their commercial interests; and often may require additional training to effectively promote and support D4Ag solutions.	**The National Seed Trade Association of Ghana (NASTAG)** is implementing a seed traceability program in the country delivered via agro inputs dealers shops. **Apollo Agriculture** in Kenya partners with local agro-dealers who join Apollo's platform to gain access to logistics and marketing services. By delivering Apollo's services to farmers, agro-dealers "see a significant business uplift as a result."
Community/ Social/ Religious Leaders	High levels of trust and respect in the community can influence community members' attitudes and behaviors. Regular gatherings provide opportunities for disseminating information.	May require substantial training and support, and their willingness to promote D4Ag solutions may depend on their personal views and interests.	**Oasis Agribusiness Limited** ("Oasis") serves over 2,300 farmers with disabilities in Alebtong, Northern Uganda, offering several digital platforms, such as USSD, call centers, and a mobile money app. Oasis provides training to community leaders using a "train-the-trainer" approach to encourage farmers with disabilities to participate in D4Ag activities.[15]

Table 3. Observed Intermediaries Models for Reaching D4Ag Last-Mile

Source: Feed the Future Flickr. Photo credit: Miles Sedgwick, Rana Labs

15 Inclusive Digital Agriculture: Making Value Chains Work for Farmers with Disabilities, GSMA, April 2021



Chapter III:

D4Ag Ecosystem Foundations

Building a robust and thriving D4Ag ecosystem, capable of achieving desired impact, requires strengthening its foundational pillars. This foundation consists of a complex and interconnected set of elements that act as the bedrock upon which D4Ag solutions are built, developed, and scaled.

Without a strong policy and regulatory environment, D4Ag initiatives may struggle to navigate compliance issues, deal with legal ambiguities, and safeguard data privacy and security. Robust networks and social capital can foster collaboration, knowledge sharing, and community building, accelerating innovation and adoption of D4Ag solutions. The right people with the appropriate skills are essential to harness the power of digital technologies and translate them into effective agricultural practices. Moreover, access to reliable data and robust digital infrastructure is crucial for the development and deployment of D4Ag tools, which rely heavily on data-driven insights to optimize farming practices and improve agricultural outcomes. At the same time, adequate funding and investment are required to fuel innovation, support startups at various stages of growth, and bring promising D4Ag solutions to market. Lastly, strong knowledge and capabilities—including research and development capacities, technical skills, and an understanding of local agricultural contexts—are necessary to adapt and tailor D4Ag solutions to the specific needs and challenges of different agricultural systems and environments in LMICs. In the following sections, we will explore each of these pillars in more detail, highlighting the challenges and opportunities they present for the growth and success of D4Ag in LMICs.

PEOPLE & SKILLS

As D4Ag ecosystems across the world have grown and matured, the need for appropriately skilled and engaged people has become only more pronounced. However, attracting and retaining quality staff possessing specialized, often cross-functional skills, like those intersecting digital and agricultural domains, has been a consistent challenge. For instance, a notable 31% of surveyed innovators (44% for sub-Saharan Africa) admitted facing some difficulties in sourcing talent, with the primary lacking skillsets being software development, data science, and business development.

A significant factor that adds a layer of complexity to this talent acquisition challenge is the difference in difficulties faced by different genders. Women, who can contribute immensely to the D4Ag sector, often face unique barriers such as cultural norms and gender roles prioritizing domestic responsibilities over advanced education and career development and discouraging them from pursuing careers in the digital sector. Moreover, a dearth of visible female role models and mentors in the digital sector often deters women from considering a career in these fields, resulting in a self-perpetuating cycle of underrepresentation. Biases, discrimination, and safety and security concerns often further dissuade women from entering or staying in the D4Ag sector. These gender-specific barriers warrant focused interventions and strategies to ensure equitable opportunities for all in the D4Ag sector.

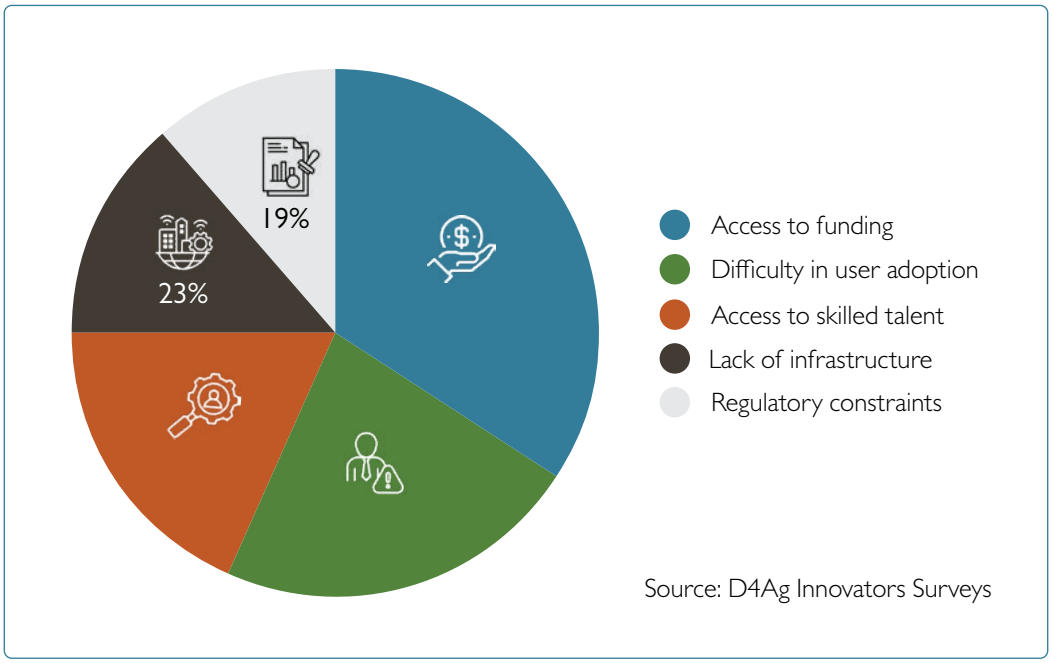


Figure 24. Top Barriers for Scaling D4Ag Solutions in LMICs.

It is worth noting that the D4Ag space in LMICs has experienced a "double brain drain" effect, where there is a talent migration from rural to urban areas, as well as to international tech hubs. Nevertheless, regional tech hubs such as Nigeria, Kenya, Brazil, and India have experienced lesser impact, offering some important lessons for those still grappling with the issue. Innovative solutions are also being adopted to mitigate the effects of the talent drain, with governments and market actors investing in locally targeted tech hubs (e.g., Sri Lanka's Nanotechnology Hub PPP), incentivizing return of highly skilled professionals (e.g., Cabo Verde tax incentives for qualified returning IT professionals), and encouraging expatriates to launch startups back at home ("sea turtles"—i.e., Intudo VC). In other cases, players are showing the power of deploying diaspora strategically (i.e., Bangladesh Angels—a network where >50% of members are "non-resident Bangladeshis")—leveraging rather than attempting to counter residency and networks abroad for capital, expertise, and partnership. In our interviews with industry experts, we have heard several times about the potential role and impact of often highly educated and experienced members of countries' diaspora in supporting the sector.

At the local level, D4Ag innovators often face stiff competition from other, often perceived as more attractive, sectors for specific skills such as software development and agronomy. This situation varies regionally, with AgTech in Southeast Asia being perceived as less attractive than other sectors such as FinTech, HealthTech, or EdTech, or in Latin America, recruiting high-quality agronomists being challenging due to competition from established corporate agribusinesses like Bayer and Syngenta, according to our interviewees. Other commonly referenced barriers were the need of being often located in a rural area, or directly engaged with the agricultural sector which is perceived as "slow" and backward-looking, as well as lower valuations and fewer opportunities for exit for the AgTech startups.

"We do not have a lot of youth transitioning from universities to the agriculture space, and this is actually because of perception in Ghana: agriculture is linked to sustenance. When youth see their parents farming, they are not making enough money, so they wouldn't want to go to the agriculture."

Agribusiness representative, sub-Saharan Africa

On the other side, universities have shown a potential to become a transformative force in D4Ag ecosystems when decision-makers within them are appropriately empowered, incentivized, and supported, as seen in India's experience.[16] Educational institutions have also emerged as crucial catalysts for promoting gender & social inclusion within the D4Ag sphere. These organizations are playing a transformative role in creating opportunities for underrepresented groups, including women, in agri-business and agri-science: by broadening educational pathways, they are providing a platform for these groups to develop their knowledge and skills, not only within the traditional agricultural disciplines but also in the wider STEM sectors.

Universities as a catalyst for D4AG advancement — India's example

India, with its rich agricultural landscape and vast pool of young, tech-savvy talent, has seen a significant rise in the adoption and innovation of D4Ag technologies. Key among the stakeholders driving this trend are Indian universities, which have leveraged their research prowess, innovation infrastructure, and industry collaboration to create a transformative impact on D4Ag ecosystems.

R&D Support: **Nurture.farm**, a leading digital agriculture platform in India, is improving their service through research partnerships with a number of Indian rice research institutes, gaining R&D support from the academia.

Industry Partnerships: In collaboration with the Tamil Nadu Agricultural University, the Tamil Nadu government created the **'Tamil Mann Valam'** portal which makes use of AI (artificial intelligence) in enabling farmers to detect soil fertility status of their land and receive SMS advisories on cultivation of crops.

Education and Skill Development: The India Agricultural Research Institute (IARI) offers a range of extension activities from supporting farmer's innovation and entrepreneurship to trainings, technological videos and e-modules. In collaboration with ICAR, the IARI has led workshops on topics ranging from doubling farmer income through smart agriculture to social science research techniques including the use of GIS for farming.

Incubation and Entrepreneurship: **AgHub** is an innovation hub at the PJTSAU (an agricultural university in Hyderabad) which supports student and rural entrepreneurship in the Agri-food Systems. For example, the Startup Entrepreneur Incubation Program help startups at the ideation stage to develop by providing regulatory support, scientific and business mentorship, product building with Aika University, fundraising or investment support, and support for obtaining patent. This program helped to develop application such as **HarSar farmAR** which combines emerging technologies to provide immersive virtual farm experience for users.

Figure 25. Universities as a Catalyst for D4Ag Advancement - India's Example

[16] IARI training, 2022; The Times of India news report, 2022

However, fragmented inclusion of emerging digital skills into curricula, absence of collaborative efforts between universities, and inconsistent digital entrepreneurship training reflect a substantial gap in the preparedness of universities in many LMICs to fully equip their students for the digital age in agriculture.[17] Addressing this gap requires concerted efforts among educational institutions, policymakers, and industry stakeholders. Multidisciplinary partnerships, continuous updates to the curriculum, exposure to real-world agricultural needs, and the inclusion of specialist modules for digital agriculture could ensure that future graduates are digitally competent and ready to innovate in the agriculture sector.

> *"Two weeks ago, we were doing our national evaluation [of university curricula]. 75% of students were saying that the curricula we have developed are archaic, they are outdated, which is true. And if they are outdated, how do you expect the innovation in AgriTech to work?"*
>
> D4Ag Expert, sub-Saharan Africa

Meanwhile, the D4Ag sector has been witnessing a paradigm shift in the profile of its founders and operators. A few interviewees noted that while the sector was initially dominated by younger, scientifically oriented individuals, there has been an increasing trend of more experienced commercial operators and seasoned founders being drawn to the space, with people stating that factors such as the COVID-19 pandemic have prompted individuals in their mid-careers to pivot and explore opportunities in the D4Ag sector. This shift in the profile of innovators is infusing the D4Ag ecosystem with a diverse mix of perspectives and experiences, fostering greater innovation and adaptability in the face of changing global and local dynamics.

> *"We also saw a change in the profile of the founders. So, before COVID-19, I would say the founders were mostly fresh out of college agronomists with very little experience in the markets, in business models, or in how to raise funds. What we saw during COVID, is a lot of people leaving their jobs, quitting, or working on startup ideas in parallel, and setting up their own startups. This was good because these founders have market experience. Usually, these founders had a longer runway because they could bootstrap, they had their own resources after working for a number of years in the corporate world. They had better business models, more connections in the market, so they were able to scale quicker."*
>
> AgTech Accelerator, Latin America

[17] CCARDESA: Assessment of Digitalization in the Agricultural Systems of the SADC Region, Situational Analysis, 2021/2022

POLICIES & REGULATIONS

Governments in LMICs continue to play a significant role in the development of D4Ag ecosystems, particularly by creating the enabling environment for broad-based agricultural transformation and inclusive market systems development. There has been a high degree of fragmentation in policies surrounding overall digital transformation in LMICs, with fragmented strategies that commonly overlook the agricultural sector. Few countries have implemented policies and/or strategies specific to digital agriculture, which often results in agricultural digitalization falling through the cracks or being handled by too many entities without clear prioritization. We have reviewed and assessed a number of digital agriculture policies, as well as their interconnections with broader digital and agricultural policies in low- and middle-income countries (LMICs).

High Policy Maturity	Mid Policy Maturity	Low Policy Maturity
Countries that are known to have comprehensive, well-integrated digital agriculture policies, with active implementation, stakeholder engagement, focus on capacity building, data privacy and security, and inclusiveness.	Countries that are known to have some digital agriculture policies but may lack in certain areas like scope, implementation, stakeholder engagement, or inclusiveness.	Countries that are known to either lack digital agriculture policies entirely or have policies that are largely on paper, with little practical implementation.
Country Examples India Ivory Coast	Country Examples Ghana Indonesia	Country Examples Venezuela Benin

Table 4. State of D4Ag Policy Maturity cross LMICs

The majority of countries reviewed display low to medium policy maturity. Despite significant progress made in the last decade to improve ICT access by governments across the globe, integrated digitalization efforts in agriculture and rural areas have been slow. For example, FAO found in 2019 that 30% of all digital government projects in least developed and developing countries are total failures, while another 50%–60% of projects are partial failures due to factors such as budget overruns and missed timing targets.[18] This suggests that the institutional support for digital transformations is still lacking in many countries.

[18] FAO: Digital Technologies in Agriculture and Rural Areas, Status Report, 2019

Ethiopian ATA
Agricultural Transformation Agency
የኢትዮጵያ ግብርና ትራንስፎርሜሽን ኤጀንሲ

ATA's model hinges on an effective blend of a clearly defined strategy, robust leadership, and the insistence on collaborative efforts within a predetermined framework, presenting a positive example of public sector engagement.

Working according to the National Strategy

The ATA supports partners to identify and address systemic bottlenecks within an Agricultural Transformation Agenda, owned largely by the Ministry of Agriculture and Livestock Resources.

Building Cross-Sector Partnerships

ATA broke down the silos by fostering partnerships that went beyond the agricultural sector. They collaborated with mobile network operators to reduce data infrastructure costs, creating synergies that were mutually beneficial. Furthermore, they initiated discussions with the Ministry of Health, learning from their successes with data utilization to enhance their own D4Ag efforts.

Ensuring Supporting Role of Donors and International Partners

ATA worked closely with international donors such as BMGF and the World Bank. These partnerships ensured that donor investments were aligned with Ethiopia's broader D4Ag goals, enhancing the impact and facilitating the realization of the country's strategic objectives.

Figure 26. Ethiopian ATA Spotlight

Different regions are faced with varying challenges in developing the digital agriculture policy space. The sub-Saharan African region faces several barriers to policy development, including difficulty in mobilizing resources, slow policy adoption, and low level of transparency. Earlier digital agriculture projects were often isolated, informal and lacking clear vision. However, much progress has been made in recent years: Between 2013 to 2023, the number of countries in sub-Saharan Africa with targeted digital agriculture policies has increased from four to 10.[19]

	SSA	LAC	SEA	SA
% (and #) of countries identified as having D4Ag specific policies	22% (10)	12% (3)	46% (6)	50% (4)
Countries identified as having D4Ag specific policies	Niger, Burkina Faso, Ghana, Benin, Nigeria, Sudan, Kenya, Rwanda, Zimbabwe, Côte d'Ivoire	Brazil, Colombia, Uruguay	Singapore, Myanmar, Thailand, Vietnam, Indonesia, Papua New Guinea	India, Bangladesh, Bhutan, Sri Lanka

Table 5. Proportion of Countries with D4Ag Specific Policies

[19] CGIAR: ICT Update issue 73, Harnessing ICT strategies for ACP agriculture, 2013

Photo credit: WRMS

Southeast Asia boasts a relatively low number of national digital agriculture programs and policies, as the governments tend to engage with the private sector and employ technologies directly, rather than focusing on policy development; however, countries including Vietnam and Thailand have recently advanced D4Ag specific policies.

South Asia has seen a limited number of countries with mature digital agriculture policies, as well as limited research focusing exclusively on this region. Agriculture practices are being transformed with digital technologies while institutional arrangements and governance are yet to catch up. One concerning trend is that in countries such as India, Pakistan, and Bangladesh, public spending into agriculture research has declined in the previous decade.

However, an absence of targeted digital agriculture policies also does not always equate to a lack of action. For example, Myanmar's government developed, deployed, and supported several D4Ag initiatives without any identified fit-for-purpose D4Ag policies.

We have observed examples of policies that often fail to enable the viability, scale, and impact of D4Ag. A prominent example can be seen in several African nations—such as Ghana, Cameroon, Uganda, or Zimbabwe—where levies on digital transactions, or e-payments, have been introduced. Several studies have found that such policies are disrupting the flow of mobile money, putting pressure on the most vulnerable social groups, ultimately posing a barrier to financial inclusion and adoption of digital technologies, including D4Ag.[20] Another example is the common policy of Bureaus of Meteorology placing climate data behind paywalls, presenting a significant barrier for D4Ag innovators, particularly startups, as it restricts their access to critical information required for creating and refining effective farming solutions. This restricted access can inhibit the growth of the D4Ag sector and potentially limit the impact of its services on farmers. Overall, among our interviewees, 19% of them admitted facing regulatory constraints in scaling up their business, with this figure reaching 33% in Latin America and the Caribbean region.

[20] Connecting Africa news report, 2023; RIS analysis, 2023

Moreover, governments may inadvertently become competitors to the private sector innovators when they engage in direct development and deployment of D4Ag solutions. For instance, government-sponsored platforms commonly offer services that are similar to those provided by private innovators, often at a subsidized cost or free of charge. While this ostensibly fulfills the purpose of affordability and accessibility, it can stifle competition, making it challenging for private innovators to sustain their business models. Besides, governments' solutions—often designed in a top-down approach without understanding of farmers' needs—result in poorly designed or inadequately resourced tools, eroding trust in D4Ag. These scenarios often result in an imbalance in the D4Ag ecosystem, creating a market that can be difficult for private innovators to penetrate and gain traction, especially when competing against subsidized or free services.

Another key concern is the potential for such public-sector initiatives to undermine trust in private innovators. For example, if a government-led initiative fails to deliver or experiences significant issues, it may cause users to lose trust in similar services, including those offered by private sector innovators. This skepticism can be a significant barrier to adoption and scale-up of digital solutions provided by the private sector.

Bridging International, National, and Regional Regulations in D4Ag

Another factor influencing the regulatory landscape is the interplay between national and regional authorities. In our interviews, we commonly heard about the misalignment between national and regional governments often limiting the support given to the D4Ag ecosystem.

At the international level, initiatives from intergovernmental organizations have played a role in knowledge sharing and collective intelligence, even if the translation to implementation remains unclear. Such strategies often come in the form of advisory and knowledge building, such as the E-Agriculture Strategy Guide published by the Food and Agriculture Organization of the United Nations (FAO) and the International Telecommunication Union (ITU), which seeks to improve the digital agriculture regulatory environment by providing Asia-Pacific countries with comprehensive guidance on developing national e-agriculture strategies and action plans. Since its first publication, the guide has been implemented in other regions, including sub-Saharan Africa and parts of Europe. Similar evaluative efforts have been done by a range of organizations including the Association of Southeast Asian Nations (ASEAN), Common Market for Eastern and Southern Africa (COMESA), and South Asian Association for Regional Cooperation (SAARC). For example, COMESA established the Digital Regional Food Balance Sheet, which aims to accelerate the implementation of digital technologies in Africa and provide better forecasts for major food commodities.

Overall, the strategic prioritization of the D4Ag, in both domestic and international arenas, currently varies greatly across different LMICs. For some, the sector is emerging as a significant part of the governmental agenda, driven by a recognition of its potential in enhancing agricultural productivity, improving food security, and boosting rural development. In these cases, governments have sought to integrate digital agriculture into their broader development and agricultural strategies, creating supportive policy environments that encourage innovation and adoption of digital solutions.

NETWORKS & SOCIAL CAPITAL

A rapid expansion in the adoption of social media, and digital modes of communication more broadly, has largely supported development of virtual D4Ag communities, both within and across LMICs. In particular, platforms such as WhatsApp and Facebook have become integral to the fabric of the D4Ag ecosystem, serving as vital networking tools and pathways for market intelligence.

YouTube channels and Facebook groups have become significant sources of information and community for farmers in LMICs. Top farming YouTube channels—such as "Farmer Leader" from India or Cambodian "Agri Pisak"—offer practical demonstrations and tips on best agricultural practices, while Facebook groups like "Modern Agriculture" serve as platforms where farmers can share experiences, ask questions, and offer advice to each other. While on one hand these digital communities provide farmers with easily accessible knowledge resources and peer support, on the other hand our interviewees have commonly voiced concerns about a lack of quality control of such information posing risks to smallholder farmers.

YouTube Channels

Name	Country	No. subscribers	Most viewed video
Farming leader	India	5.98M	16M
My kisan dost	India	1.37M	3.7M
Hello Kisaan	India	1.52M	10M
The Advanced Agriculture	India	1.12M	7.5M
Mag-Agri Tayo	Philippines/global	199K	2.6M
Agri Pisak	Cambodia	419K	13K

Facebook Groups

Name	Region	No. Number
Agriculture and young	Global	750.6K
Indian Agriculture Professionals (IAP)	India	345.6K
Agriculture/Farming The Modern Way	Uganda	216.7K
Opportunities in Agriculture and related field (SMART-AGRI)	Global	153.2K
World Agriculture Group for farmers	Global	132.4K
Organic Agriculture of India	India	116.4K
Crop farming South Africa	South Africa	115.3K

Table 6. Sampling of Top-Identified Farming YouTube Channels and Facebook Groups in LMICs

Non-textual based formats have also emerged as effective tools for delivering engaging content. For instance, the use of TikTok marketing and educational videos by innovators has demonstrated the power of visually driven content in capturing audience attention and disseminating information. During our interviews, two such innovators admitted to actively leveraging TikTok for different purposes: Southeast Asian **Verifik8** uses TikTok as a channels to advise and engage with smallholder farmers, while South American **Oxanic Grow** uses it as a marketing tool.

COVID-19: An Unexpected Accelerator for D4Ag

During the COVID-19 pandemic, smallholder farmers have been negatively impacted at every stage of the agricultural cycle. Farmers struggled with accessing technical advice and acquiring agricultural inputs, necessary labor, machinery, and logistics services, as well as eventually accessing markets to sell their produce

Planning	Production	Storage	Processing	Transport	Access to markets
• Lost access to technical advice and peer support • Inability to purchase inputs or pay for logistics	• Inability to resolve pest problems • Decreased agriculture activities supplanted by additional unpaid domestic work • Inability to hire adequate labor or machinery	• Inability to access and use storage resulting in crop wastage and reduced aggregation	• Inability to process product, resulting in crop wastage	• Higher transportation costs	• Increased crop wastage • Strained customer/ buyer relationships • Decreased negotiation power of SHFs • Increased stress and pressure to rapidly adapt

However, most of our interviewees agreed that COVID-19 has served as an accelerator for previous digital community-building efforts. The pandemic induced a shift in modes of communication and knowledge sharing, driving the transition toward international webinars and online platforms as standard practice for collaboration and knowledge sharing. Movement restrictions and inability to communicate in person boosted the adoption of digital services, such as digital advisory, mobile money, and e-commerce for ordering inputs and selling produce.

In our interviews, we have observed four key trends related to the impact of pandemic on use of digital tools in agriculture:

1. The acceptance of digital tools—particularly digital advisory services, mobile money platforms, and digital marketplaces—has experienced significant growth among smallholder farmers.
This is primarily due to the farmers' increased exposure to a wider range of digital technologies. As smallholders become more familiar with these tools, their understanding and trust in these systems grow, leading to higher acceptance levels.

2. Agribusinesses were forced to accelerate the adoption of digital technologies in their daily operations, which has increased their resilience in the face of COVID-19 disruptions.
The pandemic posed numerous challenges to traditional ways of doing business, including supply chain disruptions, workforce limitations, and reduced physical interactions. By integrating digital technologies, businesses have been able to maintain operations, ensure continuous communication with suppliers and consumers, and implement innovative solutions such as remote monitoring and management of agricultural operations.

3. The use of social media platforms, such as WhatsApp and Facebook, for peer-to-peer communication and accessing agricultural markets has also seen a surge.
WhatsApp, with its user-friendly interface and wide reach, has become a popular platform for creating virtual marketplaces. Farmers join specific groups based on their products and geographical location, where they can share information about their produce, negotiate prices, and arrange for delivery.

4. Although fewer digital solutions have been launched during the pandemic years, existing providers often broadened their service offerings.
The crisis has revealed new needs and emphasized the value of digital solutions in overcoming challenges. As a result, many providers have expanded their services to include features like digital payments, online training, remote consultation, real-time market data, and more.

This shift, precipitated by necessity, has nonetheless opened opportunities for even broader, more inclusive engagement within the D4Ag space. The lessons learned and practices adopted during this time will likely continue to shape community engagement strategies in the post-pandemic world.

Figure 27. Effects of Covid-19 on agricultural cycle and D4Ag

> *"Farmers like YouTube and TikTok because it is entertaining. A few months ago, we developed a whole strategy on TikTok. So, we actually engage a lot of farmers through TikTok. We do live videos. It's very successful actually. I mean, for me, it was a bit weird at the beginning because to engage them, we had to create funny videos. It's not professional at all, I recorded myself doing a yoga demonstration at one point, but it works so well because they work all day in the field, they're tired, and at the end of the day, they wanna see something fun. That's literally how we engage with them. And then from time to time, we're gonna do live videos where we actually do a training, which is more serious. But we make it short so that it's not boring, but we actually managed to get a lot of attention through this."*
>
> D4Ag Innovator, Southeast Asia

KNOWLEDGE & CAPABILITIES

Digital literacy in LMICs varies widely and is influenced by numerous factors, forming a complex spectrum across geographies and various sub-populations. For instance, younger individuals often display higher digital literacy levels than older generations, given their early exposure and frequent interactions with digital technology. Similarly, digital literacy amongst rural populations often lags behind that of urban populations.

	Regional literacy rate*	Rural literacy rate*	Digital literacy rate*
South Asia	73.3%	68.0%*	32.6%
Southeast Asia**	<96%**	84.2%*	31.17%
Sub-Saharan Africa	67.3%	43.5%*	19.41%
Latin America and the Caribbean	94.1%	87.2%	31.23%

* Estimation based on available country-level data
** Including East Asia and the Pacific

Table 7. Literacy Rates Across LMICs.

Despite some advancements and the considerable public and private investments in digital infrastructure, digital literacy continues to present a major obstacle to the full use and uptake of D4Ag tools. Many people, especially in rural areas, still struggle with the basics of operating digital devices like smartphones and tablets. This knowledge gap, which often begins with understanding when a device is connected to the internet or the differences between 2G and 4G networks, can hinder the optimal use of D4Ag tools.

Interestingly, India presents a contrasting scenario, where several interviewees suggested that digital literacy among target users is underestimated. A few Indian innovators even mentioned that their customers found their technology too simple, or they underestimated the level of digital literacy of rural consumers when designing the products:

> *"I have a counter view to that [the need to adapt technology to serve lower literacy users]. Most of our users are younger people below 35, and the feedback we got was that our app is not as sophisticated. The global companies have set the bar so high that anyone in rural India now expects a very high level of UX and UI experience".*
>
> D4Ag Innovator, South Asia

This potentially points toward the need for a more nuanced understanding of digital literacy levels across different contexts, and the importance of tailoring D4Ag solutions to match the abilities and expectations of their target users.

However, even basic literacy remains to be a significant barrier to digital adoption in some LMICs. This is particularly pronounced in sub-Saharan African countries like Chad, South Sudan, or Mali, where adult literacy rates still stand at <30% (with female literacy rates as low as 18%), meaning that a significant proportion of the population is unable to fully engage with digital platforms or access digital information.

> *"We are seeing a lot of people who do not know how to read or write their names, but they are sending audio messages through WhatsApp, and with some support, they register their Facebook profiles. Even if they don't know how to read, they are quite tech savvy with social media and mobile money."*
>
> Agricultural Alliance, sub-Saharan Africa

"We need to invest in farmers' training and give time for them to adapt, to make sure that they feel comfortable with these kinds of apps. They often don't have the proper capacity to use these apps. So perhaps you need to prepare more simple apps to begin with, and not just to bring apps that are developed already in Western countries for big farms where farmers' literacy is quite high. Rather you need to invest in producing much simpler apps, taking into consideration the farmers age group, prevalent social norms, and so on and so forth".

D4Ag Expert, USA

Several alternative delivery channels, such as video delivery, or IVR for individuals with low literacy levels, have shown promise in promoting greater inclusion and impact. However, they come with their own limitations—such as high costs or challenges of digitizing local languages, especially those with complex technical taxonomies, for IVR systems.

Evidence from alternative delivery channels in low-literacy settings

FM RADIO

FM radio is one of the oldest and most successful ICT tools: farmers rely on crop advice, weather forecasts and market information. It is available to practically everyone and broadcasts in local languages, however its main limitation is that it is a one-way communication channel, in addition to programs being accessible only when broadcasted live. **Farm Radio International** combines radio with mobile phone and IVR to enable listeners to communicate with broadcasters, conducting polls, providing agri advisory, sharing reminders and summary of the programs, and even connecting farmers to markets.

IVR

IVR is especially prominent in Sub-Saharan Africa: according to **VOTO** Mobile survey, more than 95% of participants preferred IVR over SMS. VOTO also found that with IVR people answer more questions; stay on the phone longer, with fewer barriers to participant engagement. Our interviews with Sub-Saharan African innovators, such as **M-SHAMBA** and **Brastorne** support the evidence that including IVR increases engagement and impact of D4Ag solution in low-literacy settings.

VIDEO

Digital Green involves local farmers, who suggest video ideas and participate in the creation of storyboards and scripts. This collaboration results in highly localized capacity-building videos, featuring local individuals. Viewers get the chance to watch their peers and acquaintances share personal experiences with new agricultural practices. They're also asked which of these practices they're likely to adopt. A 2022 study of the impact of Digital Green's found that the video-mediated approach led to a 6% increase in farmers' uptake of the recommended technologies in the first year of the experiment.

Figure 28. Evidence from Alternative Delivery Channels in Low-literacy Settings[21] [22]

[21] Gashaw et.al. Accelerating technical change through ICT: Evidence from a video-mediated extension experiment in Ethiopia, World Development, 2023

[22] 4 Ways We Can Better Engage Smallholder Farmers Using ICT. ICTworks, April 13, 2016.

In response to these challenges, some innovators in the D4Ag space are exploring ways to make their tools as simple and enjoyable to use as possible. This approach is evident in some attempts of the "gamification" of certain D4Ag tools, where game-like elements are incorporated to stimulate user engagement and learning. For example, Southeast Asian Agri-Fintech platform **Agrig8** has developed a farmer engagement app inspired by and designed to mirror "Tamagotchi"—a well-known digital pet-care game, to make it user-friendly and accessible for the users.

AgriG8 user interface leveraging gamification.

Given the challenge of directly educating users at scale, more attention is being given to models when physical delivery channels support digital ones, such as the one employed by **Agrithmics** in Sri Lanka. These models often involve extending physical cards, biometric identifiers, and other non-digital means to small-scale farmers, thus allowing them to participate in digitally enabled systems without requiring individual digital literacy.

FUNDING & INVESTMENT

Funding and investment play a pivotal role in fueling the growth and sustainability of D4Ag ecosystems in low- and middle-income countries; it is a complex and multifaceted domain that extends beyond merely providing financial resources to individual innovators.

Funding for Individual Innovators: As innovators strive to develop innovative solutions to pressing agricultural challenges, they often face considerable resource constraints: Access to funding was the most commonly referenced barrier by our interviewees, with 58% of respondents saying that they are struggling to attract enough funding. Adequate capital is required only to support the initial stages of research, development, and product market readiness, but also to aid in scaling operations, enhancing innovation, building capacities, and mitigating inherent risks associated with the sector. We will delve into the details of investments in D4Ag solutions in Chapter 4 of this report.

Infrastructure Funding: As D4Ag relies heavily on technology-driven infrastructure—including physical and digital networks, data centers, hardware and more—investment in infrastructure is vital for the successful deployment and

scalability of digital agriculture. It facilitates the connectivity and interoperability of various components, enabling real-time monitoring, analysis, and decision-making. However, infrastructure receives disproportionately low attention from the public sector, which is expected to be the main driver of infrastructure development: Even though there is no clear estimate for LMICs, according to OECD, in 2019–2021, the public sector had invested only US$17 billion into agricultural infrastructure (in the OECD area), constituting merely 2% of total spending on agricultural sector.[23]

Research and Development (R&D) Funding: R&D funding fuels the scientific and technological advancements that lay the foundation for the next generation of agricultural innovations. It supports academic research, private-sector development, and collaborative initiatives that drive progress in areas such as genetics, automation, data analytics, and more.

Even though public sector support of agriculture has continued to grow in recent years,[24] it often fails to meet its stated aims of improving food security, livelihoods, and environmental sustainability. According to the study conducted by OECD in 2021, "only one in six dollars of budgetary support to agriculture globally is spent in ways that are effective in promoting sustainable productivity growth and agricultural resilience." In contrast, half of support to agriculture is market distorting, inequitable and harmful to both the environment and global food security, according to the report.[25] A 2020 IFPRI study has estimated that LMICs have spent around US$28.2 billion in 1981-2016 on agricultural R&D, with US$2.3 billion spent in sub-Saharan Africa, US$4 billion in India, US$3.6 billion in APAC (ex-China and India), and US$4.7 billion in LAC.[26] This represents an annual investment of only ~US$750 million *per year* across LMICs, a small fraction of what is required to keep up with and advance the development of transformational agricultural innovation. According to Rosegrant, Sulser, and Wiebe, (2022), the investment gap in research and innovation for sustainable agriculture intensification in the Global South currently stands at US$10.5 billion annually. [27]

Access to Credit for Farmers and Farmers Organizations: Providing financial access to farmers is a crucial aspect of the D4Ag funding ecosystem. Farmers rely on credit to acquire necessary agricultural inputs. Without personal savings, they often resort to borrowing from informal sources like friends, relatives, or moneylenders who often charge exorbitant interest rates and impose unfavorable terms, potentially rendering many farming activities economically unviable. According to FAO, in 2020 overall credit to agriculture (including farmers, cooperatives, and agribusiness) reached US$1,136 billion, an increase of US$201 billion (or 21%) compared with US$935 billion in 2012. Yet, the growth in credit to agriculture was slower than in other sectors, as the share of agriculture in total credit slowly declined between 2012 and 2020 from 2.67% to 2.38%. [28]

Even though significant strides have been made in financial inclusion, in 2021, around 1.4 billion of adults were still unbanked, with women

[23] OECD Agricultural Policy Monitoring and Evaluation report, 2021.
[24] OECD, Government support to agriculture is increasing, 2022
[25] OECD Agricultural Policy Monitoring and Evaluation report, 2021.
[26] Key trends in global agricultural research investment. IFPRI ASTI, 2020
[27] Rosegrant Mark W., Sulser Timothy B., Wiebe Keith. Global investment gap in agricultural research and innovation to meet Sustainable Development Goals for hunger and Paris Agreement climate change mitigation. Frontiers in Sustainable Food Systems. 6. 2022. DOI: 10.3389/fsufs.2022.965767
[28] Credit to agriculture. Global and regional trends, 2012- 2020. FAOSTAT Analytical Brief 38

constituting 54% of this number, according to Findex.[29] There is definitely an urban-rural gap in access to finance; however, the available data is quite sparse and inconsistent across LMICs. For example, in Cambodia and Zambia, adults in urban areas are almost twice as likely to have an account as adults in rural areas; while in countries like Bangladesh, India, and Malaysia, there is virtually no difference in account ownership between adults living in urban and rural areas.

DATA AND INFRASTRUCTURE

According to the CTA 2019 report, D4Ag infrastructure, sometimes referred to as D4Ag "middleware" or "midstream technologies," forms the foundation for digital agriculture transformation. It comprises the hardware, software, and data assets necessary for the operation of D4Ag solutions, as well as the broader enabling environment that supports their use and scalability.

The foundations for robust and effective D4Ag solutions are rooted in the quality, accessibility, reliability, sustainability, and relevance of these infrastructures. Each attribute plays a crucial role in determining the effectiveness and potential of digital tools and services designed to boost productivity, enhance resilience, and improve the livelihoods of smallholder farmers and other agricultural stakeholders.

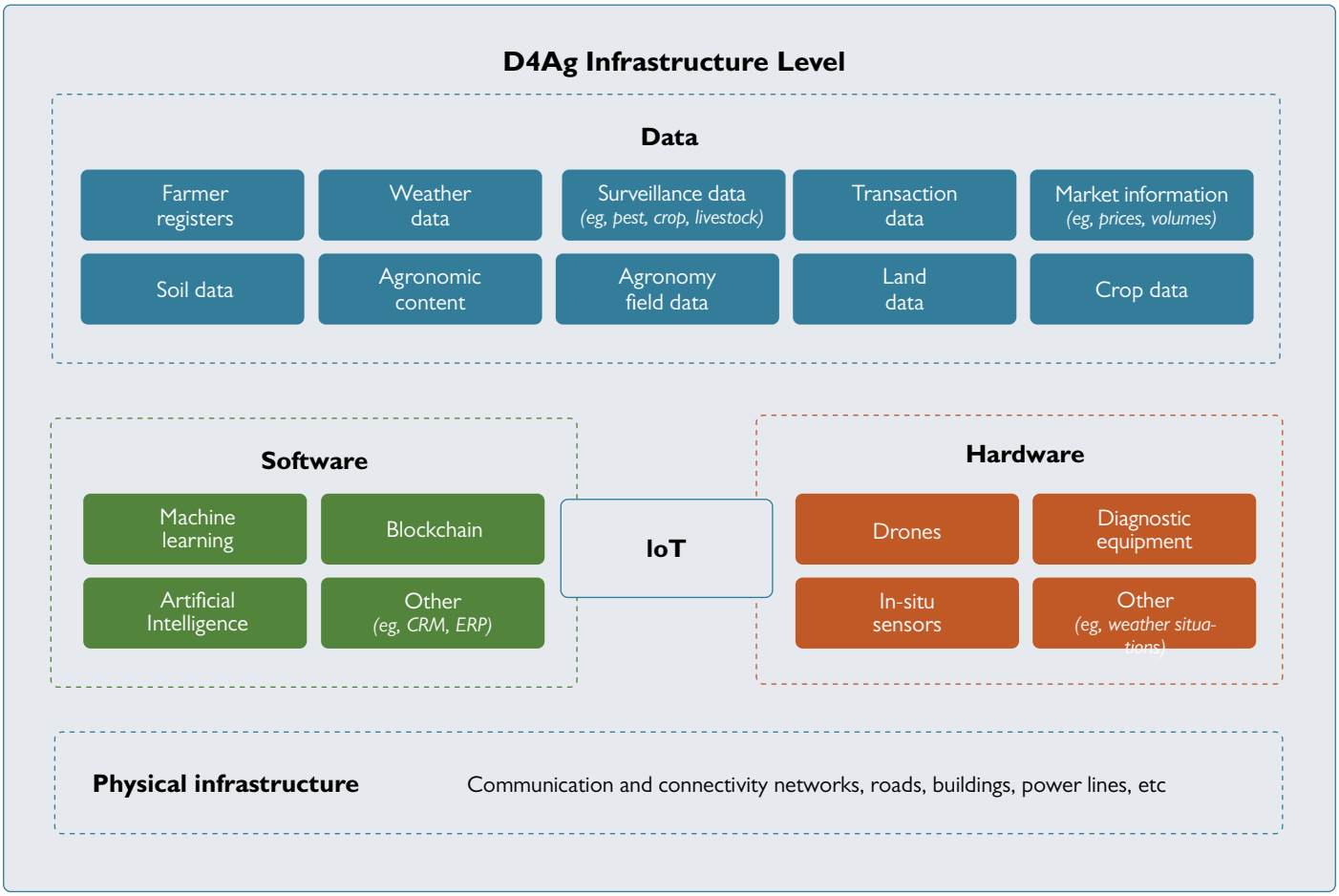


Figure 29. D4Ag Infrastructure Level

[29] The Global Findex Database 2021

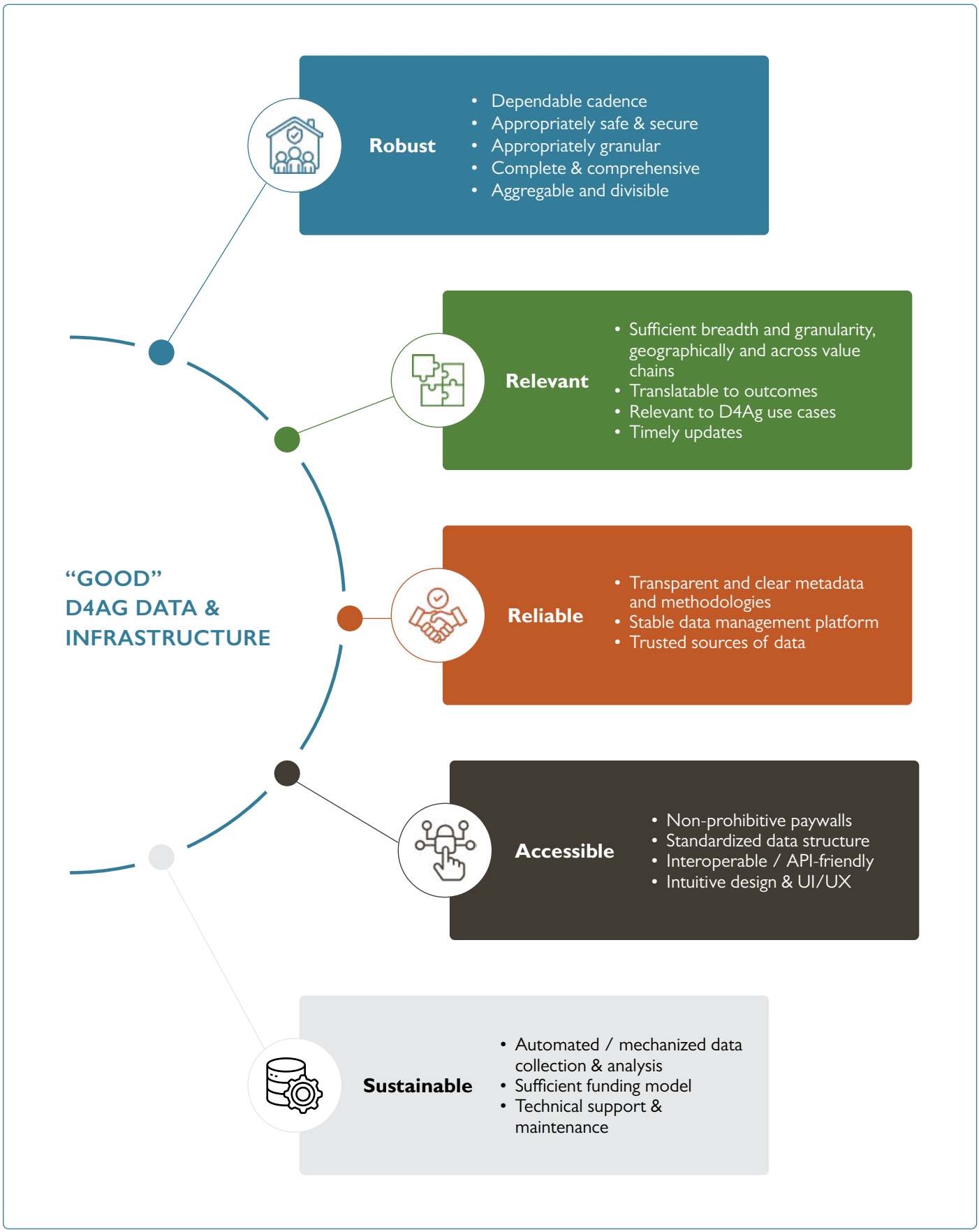


Figure 30. What 'Good' Looks Like for D4Ag Data & Infrastructure

1. **Robust:** A good D4Ag data and infrastructure in LMICs should be robust, capable of withstanding various challenges, including those brought by rapid technological changes, economic fluctuations, and evolving agricultural practices. It should be resilient to both temporary disruptions , such as those caused by extreme weather events or malicious actions, and longer-term trends, such as those driven by climate change or shifting market dynamics. Furthermore, the infrastructure should be able to handle large volumes of data from multiple sources, integrating them seamlessly to provide valuable insights for users. This requires an architecture that is both flexible and scalable, capable of expanding to meet growing data needs and adapt to emerging technological advancements.

2. **Accessible:** Accessibility is key to ensuring the successful implementation and impact of D4Ag initiatives. Data and digital solutions should be accessible to all relevant stakeholders, regardless of their location, socioeconomic status, or level of digital literacy. This means designing user-friendly interfaces, providing multilingual support, and ensuring compatibility with a wide range of devices, including those available to small-scale producers in LMICs. It also involves efforts to bridge the digital divide, such as capacity-building programs to enhance digital literacy, and initiatives to expand network coverage and internet access in rural and remote areas.

3. **Reliable:** The reliability of D4Ag data and infrastructure is crucial in building trust among users and encouraging uptake. The systems should consistently provide accurate, up-to-date, and relevant information that users can depend on to make informed decisions about their agricultural practices. This requires rigorous data quality control measures, reliable data sourcing, and robust algorithms that minimize errors and inconsistencies. In addition, the digital infrastructure should have minimal downtime, with strong security measures in place to protect against data breaches and ensure user privacy.

4. **Sustainable:** Sustainability is a critical factor in the long-term success of D4Ag initiatives. This involves both environmental and economic sustainability. From an environmental perspective, the digital infrastructure should aim to minimize its carbon footprint, for instance through energy-efficient data centers and the use of renewable energy sources. Economically, the D4Ag infrastructure should strive for a business model that ensures its continued operation and development without constant reliance on external funding. This might involve, for example, the creation of value-added services for different stakeholders, or public-private partnerships that leverage the strengths and resources of different sectors.

5. **Relevant:** Finally, a successful D4Ag data and infrastructure must be relevant, delivering data and insights that directly support the needs and challenges of its users. This involves a deep understanding of the local agricultural context, including the specific crops, climate conditions, market dynamics, gender divisions, and cultural practices. It also requires a user-centered design approach, involving end users in the development and refinement of digital tools to ensure that they meet their needs and preferences. Moreover, it should provide an opportunity for all relevant stakeholders, including users, to have a stake in the ecosystem's governance and in the value it generates. Lastly, the relevance is enhanced by providing timely and actionable insights, tailored to the specific decision-making contexts of different users—from small-scale farmers to agribusinesses and policy makers.

D4Ag Data

Despite the increase in data availability, several factors such as accessibility, comprehensibility, granularity, and data integrity continue to limit their wider contribution to the D4Ag ecosystem. Even though there is a growing emphasis on generating farm-level and enterprise-level data points, which offer more tailored and commercially relevant insights, the access to these data points is not widespread and often comes at significant cost to innovators. One of the counterexamples to this, however, can be the National Bank for Agriculture and Rural Development (NABARD) in India, which is publicly geotagging cold chain storage facilities, adding value to marketplaces and other D4Ag solutions.

It has been estimated that the average farm generated around 190,000 data points *daily,* and this figure is expected to skyrocket to 4.1 million data points per day by 2050.[30] The ownership of this farm-level data, often referred to as "the new cash crop" due to its monetization potential, remains contentious, and while farmers generate this data, it's typically owned by the AgTech developers. Moreover, with the evolution of D4Ag, an often-highlighted opportunity has been to move beyond "registries" to "profiles" of farmers, partner enterprises, and producer organizations. However, the duplication of foundational data points remains an issue and there are limited pathways to share this data.

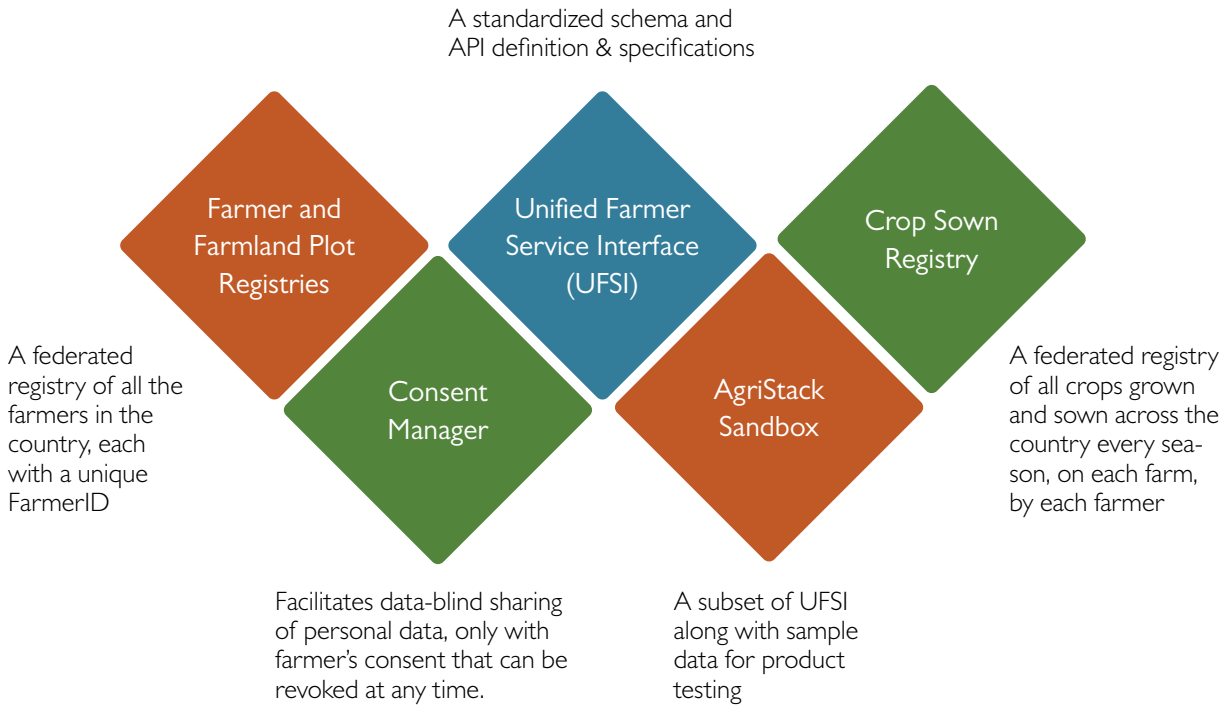
It is worth noting the few countries, like India with its AgriStack initiative, that have ventured to invest in more sophisticated agricultural public data warehousing and analytics infrastructure. AgriStack is following the concept of Digital Public Infrastructure (DPI)—digital solutions that enable basic functions essential for public and private service delivery, i.e. collaboration, commerce, and governance, similar to existing public road infrastructure, but online.[31]

Agri Stack is a set of data, policies and regulations, data exchange, and a consent layer intended to allow private sector stakeholders to access datasets and innovate.[32]

[30] A Roadmap for Building the Digital Future of Food and Agriculture (worldbank.org)
[31] Digital public infrastructure, platforms and public finance | ODI: Think change
[32] How digital public infrastructure could transform farming | World Economic Forum (weforum.org)

INDIA'S AGRISTACK

India's agriculture sector is experiencing a significant digital transformation, marked by the introduction of AgriStack, a dynamic, open database encompassing farms, for individual farmers, and crops grown. While still in the development, the following building block have been planned for AgriStack:



AgriStack aims to:
1. Improve goverment benefits/schemes delivery so they rech all Indian farmers faster and more easily.
2. Create a presence-less layer for quick identification and authentication of the farmers
3. Lower the cost and risk of agricultural services for farmers and agri-credit, finance, inputs, and other service providers.
4. Enabler easier scheme convergence between agri-allied Minitries and State Governments to better serve the Indian farmers.
5. Accelerate innovation in products & services by AgriTechs with easier access to high-quality data.

Figure 31. India's AgriStack

In parallel, the last decade has witnessed the advancement and consolidation of open data sources and initiatives. Examples include GARDIAN from CGIAR, USDA Ag Data Commons, and the Open Ag Data Alliance hosted on GitHub. These have been instrumental in promoting a more open and accessible data environment.

GARDIAN (CGIAR)	Ag Data Commons (USDA)	Open Ag Data Alliance (GitHub)
GARDIAN is CGIAR´s flagship data harvester. It enables the discovery of publications and datasets from across the thirty-odd institutional publications and data repositories from CGIAR Centers and beyond.	The USDA's Ag Data Commons provides central access to a wide variety of open agricultural research data funded in whole or in part by USDA, functioning as a FAIR-compliant repository.	The Open Ag Data Alliance is an open project designed to bring interoperability, security, and privacy to agricultural data, focusing on the rights of farmers over the data generated on their farms.

Table 8. Open Data Initiatives Examples

Farmer-Centric Data Governance

In the realm of agriculture, data governance has emerged as a critical factor in leveraging the potential of agricultural technologies while safeguarding farmers' interests. One structure proposed to support a farmer-centric data governance strategy is the appointment of an independent, non-commercial "data steward/ trustee" at industry, country, or regional levels. The purpose of such a role would be to set data collection and sharing principles, regulations, and management practices. This requires a unique operating model, suitable enabling technologies, and a compelling business case that generates returns on shared data. In some cases, these returns could potentially be in kind, thus incentivizing further sharing and usage of the data.

The latest report "Farmer-Centric Data Governance: Towards a New Paradigm," [33] funded by USAID and the Bill & Melinda Gates Foundation, explores the transformative power of adopting a farmer-centric approach to data governance, aiming to empower farmers and ensure they benefit equitably from their own data. The proposed farmer-centric data governance models are a significant step toward ensuring that farmers, as primary data producers, can benefit economically from their own data. This new paradigm is a valuable resource for policymakers, donors, companies, and organizations involved in digital agriculture technologies or managing data governance structures, offering a roadmap for creating a more equitable and sustainable agricultural sector.

Photo credit: WRMS

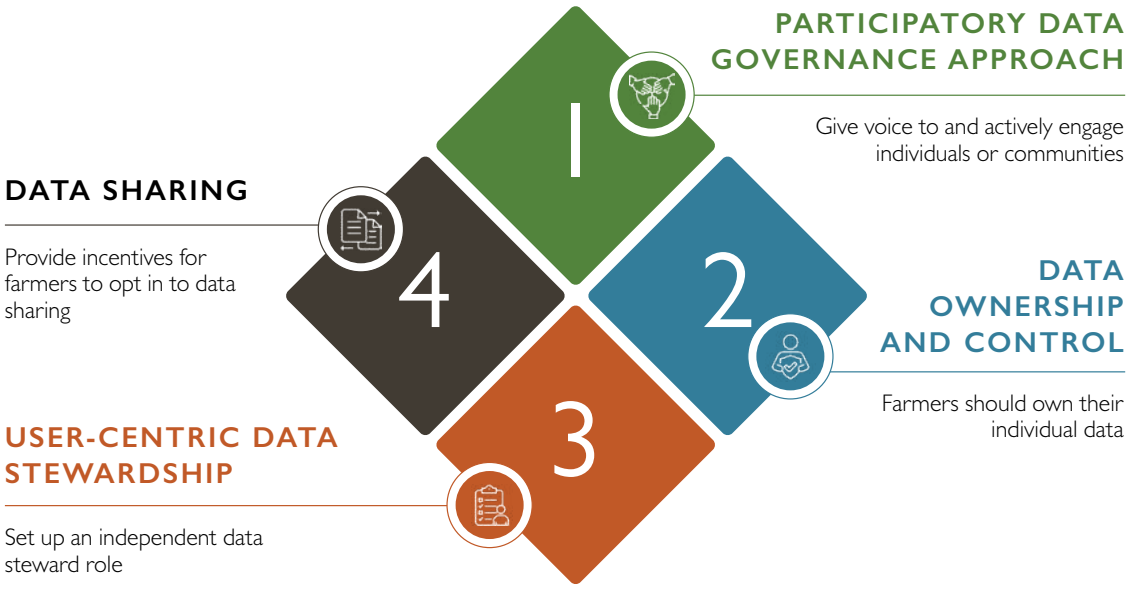
[33] USAID: Farmer-Centric Data Governance: Towards a New Paradigm, 2023

UNRAVELING THE PARADOX OF DATA USAGE - FARM DATA AS THE NEW CASH CROP

The agricultural sector is increasingly data-driven, but the current state of data governance presents significant challenges. Farmers, who are themselves major producers of data, often do not benefit economically from their own data. This paradox is compounded by the lack of equitable data governance models that prioritize farmer participation and protect farmers against potential disadvantages and exploitation. The USAID- and BMGF-funded report "Farmer-Centric Data Governance: Towards a New Paradigm" proposes a shift in the agricultural data governance model.

Farmers Taking the Reins of Data Governance

Central to this shift is the concept of farmer-centric data governance. By prioritizing farmer participation, this approach redirects power and profits back to those at the heart of agriculture. It emphasizes the need to protect farmers from exploitation and ensures their active involvement in decision-making processes. The report recognizes and focuses on four building blocks to build new user- centric data governance paradigms:



The report proposes a shift towards more equitable and participatory models of data governance in the agricultural sector via the following models:

Model	Key Features
Data Collaboratives	Cross-sector, public-private collaborations aimed at data collection, sharing, and processing for societal benefit. They allow partners to write their own rules on data exchange and stewardship, and can provide broad access to proprietary or siloed datasets.
Data Commons	Pool and share data as a resource with a high degree of community ownership and leadership, addressing power imbalances by democratizing access to and the availability of data. Data stewardship is a prerequisite.
Data Cooperatives	A voluntary communal pooling of individuals' or organizations' data for mutual benefit that grants members more control to manage, curate, and protect access to their data. Co-ops are democratically controlled and autonomous.
Data Fiduciary Models and Marketplaces	Governance models in which data stewards act as intermediaries to manage access to data. They create a trusted environment between stakeholders. Data marketplaces are platforms where data providers and consumers can trade data assets.
Indigenous Data Sovereignty	Models that shift access and control over data to indigenous people. They illustrate the importance of sovereignty, unique indigenous knowledge, and cultural considerations to self-determination.
Data Trusts	Legal mechanisms providing independent stewardship of data for multiple parties. Trustees are required to act with undivided loyalty and dedication to the interests and aspirations of the beneficiaries.

The report argues that farmer-centric data governance models are essential for the sustainable and equitable growth of the agriculture sector. By embracing the transition to these models, stakeholders can create a dynamic ecosystem that empowers farmers, harnesses the potential of data, and paves the way for a prosperous future in agriculture.

Figure 32. Farmer-Centric Data Governance

The Role of Data in Different Agricultural Sectors

There is a strong consensus that significant growth opportunities exist in expanding the available data to support the viability and impact of D4Ag; however, when considering the value chain and different geographical contexts, livestock and aquaculture seem to lag behind cropping. This might be due to various factors such as the inherent complexities of these sectors, the relatively lower digital penetration, or possibly because the return on investment in data applications may not be as immediately apparent or tangible compared to crop-based agriculture.

Notably, there are a few outliers where digital hubs exist and prosper, beyond cropping. For instance, in Indonesia, the aquaculture sector has made significant strides in leveraging data for improved productivity and sustainability. A conducive policy environment, availability of digital infrastructure, and strong local demand for fish products have catalyzed the growth of data-driven aquaculture in this region.

Indonesia's AquaTech Boom

Indonesia is the world's third largest aquaculture producer, after China and India, with 90% small-scale fisheries dominating the market. The country's rapidly growing aquatech startups are aiming to help the industry to realize its full potential. The sector has been attracting a lot of interest from the investors, with eFishery reaching unicorn status in 2023.

	Tumbuh Bersama eFishery	aruna	JALA	DELOS
Founded	2013	2016	2015	2021
Funds Raised (USD)	342.9M	100M	12M	8M
Valuation (USD)	1.3B	~200M	unknown	unknown

Figure 33. Indonesia's Aquatech Boom

Similarly, in India, the dairy sector stands out as a hub for D4Ag innovation. Dairy production in India is a significant part of the country's agricultural economy, and the application of data-driven tools and technologies has been increasingly recognized for its potential to increase yields, improve animal health, and optimize resource use. An example of this is the use of IoT technologies for monitoring animal health, milking processes, and tracking product quality and safety.

Source: Feed the Future Flickr. Photo credit: Sanjoy Chandra Bhattacherjee for ACDI/VOCA

		Funds raised
stellapps	**Stellapps** is an IoT startup digitizing milk production, procurement and cold chain management via a suite of apps and sensors in rural India.	$36.8M
prompt The pursuit of purity	**Prompt** provides cloud- based dairy equipment (hardware and software) from farm management and milk collection, to quality analysis and preservation, across 65,000+ villages in India.	unknown
Country Delight	**Country Delight** works with more than 10,000 smallholder farmers across India and provides everyday milk testing and cold supply chain in places with insufficient infrastructure	$158.2M
MilkLane	**Milklane** is supporting farmers through extensive training and extension service. It's village-based cooling and collection centers are run by local entrepreneurs and are monitored in real time via its digitally-enabled supply chain.	$7.9M
milk mantra	Sourcing milk from 75,000+ smallholder farmers, **Milk Mantra** has rolled out a network of milk coolers in villages. The company also offers extension services to the farmers.	$39.5M

Figure 34. India's Dairy Innovation Landscape

Photo credit: Tepbac

These examples underscore the potential for data-driven growth in sectors beyond crop-based agriculture and across different geographical contexts. However, realizing this potential fully would require addressing the sector-specific and regional challenges, and creating an enabling environment that encourages the adoption of data-driven approaches in these less explored areas of D4Ag.

Software

From a software perspective, there has been a surge in the development and accessibility of sophisticated capabilities such as machine learning, blockchain, artificial intelligence, systems integration, and CRM in D4Ag, which is reflected in the proportion of tools leveraging such enabling technologies. However, there is growing acknowledgment that emerging technologies have not fully lived up to expectations and pose challenges such as costs and complex implementation processes in LMICs, potential exclusion of those with lower digital literacy, and reliance on connectivity infrastructure that is often insufficient in rural areas. The increased complexity and sophistication of these tools can also lead to problems of transparency and interpretability, raising questions about the accountability and ethical implications of AI-driven decision making in the agricultural sector.

Inclusivity and responsible use of these tools have gained attention, with concerns raised about the potential for AI models to exacerbate inequalities—for instance, through the exclusion of women or lack of natural language processing for minority languages. The concern about inclusivity and responsible use of AI and other emerging technologies in the D4Ag sector is a sentiment echoed from multiple corners, including but not limited to donor organizations, policymakers, and civil society.

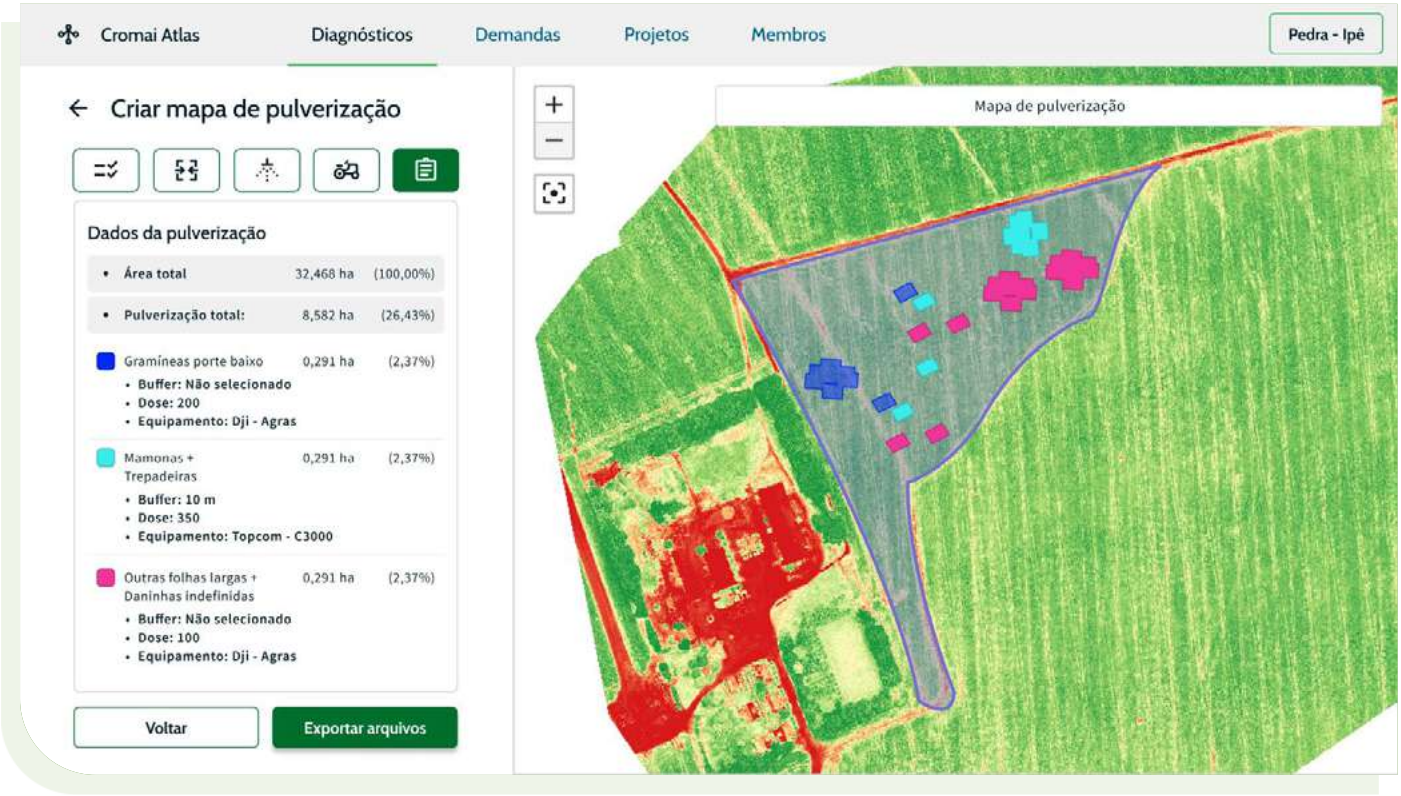


Photo credit: Cromai

For example, USAID's Artificial Intelligence Action Plan aims to prioritize responsible use of such technologies: "When we turn to AI, we must commit to do so with full appreciation of the technology's potential for benefit and harm. For AI, this includes constructing appropriate safeguards, investing in relevant talent, and understanding how AI is connected with the broader digital ecosystem and the different stakeholders therein." Private solutions providers are also turning their attention to inclusivity and responsibility in use of AI: for example, **Cropin** states that their **SmartRisk** AI-based risk assessment model considers ethics of AI in agriculture, including consumer privacy, data security, fairness, transparency, and accountability: "CropIn understands the importance of data sensitivity. Any confidential information or data that the client submits to CropIn belongs to the client and, under no circumstance, will we share the data with a third party, except with the written consent of the client."[34]

The advent of AI and automation technologies presents a potentially transformative solution to the challenges faced by agrifood systems in LMICs. These technologies are capable of automating complex tasks and decision-making functions, thereby increasing productivity, optimizing costs, fostering social inclusion, and building climate resilience. However, as we are still in the early stages of this journey, the benefits that AI can bring to smallholder farmers largely depend on the approach to its deployment and may also bring unintended consequences and risks that could limit their impact as they disrupt agrifood value chains.

[34] CropIn News, 2021

LEVERAGING AI AND AUTOMATION FOR INCLUSIVE ADVANCEMENT OF AGRI-FOOD SYSTEMS

The USAID- and Bill & Melinda Gates Foundation-funded report "Inclusively Advancing Agri-Food Systems through AI and Automation" identifies numerous instances where AI and automation technologies are already applied on the back-end and delivered to smallholder farmers using a combination of low-tech delivery channels, in-person intermediary networks, and partnerships with value chain stakeholders willing to subsidize the cost of the solution. Such an inclusive deployment approach ensures that the benefits of these technologies are accessible to all stakeholders in the agri-food value chain.

Despite these benefits, a significant concern is the potential for disproportionate benefit distribution. This uneven distribution can have implications on competitive dynamics, access to economic opportunities, social inclusion, and potentially lead to adverse climatic effects.

Agricultural Productivity Risks:

- Manual labor shedding: Automation can reduce the need for on-farm labor, potentially negatively impacting employment for smallholder farmers.
- Inaccurate insight due to data biases: AI solutions might provide skewed or incorrect insights, leading farmers to make wrong decisions that can negatively impact productivity.
- Inequitable distribution of benefits: Differences in adoption rates of AgTech solutions can result in a widening productivity gap among the producers, favoring those who can afford the technologies.

Economic and Competition Risks:

- Inferior products: Digital platforms that provide smallholder farmers with easier access to inputs from a variety of suppliers may expose them to an increased risk of purchasing inferior or counterfeit products.
- Inadequate consumer protection: Out-of-date policies and regulations that do not cater for the dynamics of new technologies may not protect consumers from new risks. For example, data monetization business models can result in the third parties accessing farmer information through AgTech service providers.
- Data security risks: Improper use of data and failure to engage with the most vulnerable of SSPS can negate the positive opportunities for inclusion in the agricultural sector.

Agricultural Climate Resilience Risks:

- Unjust denial of insurance payouts: Geographic and climatic nuances might not be factored into insurance models based on satellite data, leading to unfair denials of policy payouts for smallholders.
- Broader climate resilience risks: The benefits of AgTech solutions for climate resilience could be offset by adverse knock-on effects, such as soil degradation and water pollution from intensive farming practices, or increased carbon emissions from data centers needed to support smart farming technologies.
- Environmental impacts: Improper e-waste disposal from widespread use of smart farming technologies can lead to serious environmental and health hazards. The mining practices for rare earth minerals, necessary for many smart devices, also carry significant environmental costs.

In conclusion, while AI and automation are already inducing transformative changes in agri-food systems, it is imperative to implement strategic interventions to ensure that these changes are inclusive and benefit all stakeholders equitably.

Build robust technology and data infrastructure	Develop solutions that are farmer-centric, scalable, and financially viable	Provide support for managing the demographic and green transitions	Promote ethical AI and data governance
• Create an agricultural data exchange • Reduce the cost of on-farm hardware • Supporting developers of white-label software infrastructure • Promoting research into inclusive agricultural AI	• Scale up trusted intermediary networks • Provide technical assistance to climate-smart advisory • Empower farmer organizations for bottom-up development of FMS	• Provide vocational training and apprenticeships to equip rural youth and women • Expand support for productive employment • Examine the potential for harm in digital market conduct • Promote ERP among AgTech innovators	• Develop ethical impact assessment framework for the use of AI in agriculture • Pilot farmer-centric and participatory data governance • Establish regional AI labs • Provide support against unethical AI decision-making

Figure 35. Inclusive Use of AI and Advanced Software Infrastructure in D4Ag

Hardware

When considering hardware requirements, the scale of investment varies significantly depending on use cases. In most scenarios, the cost of such hardware has been absorbed into the unit economics of D4Ag solution providers, limiting uptake in many settings and impacting business models, depending on capital- and cost-intensity of hardware solution. Hardware-as-a-Service (HaaS) models have emerged, particularly around drone operation, offering opportunities for rural skills-building and entrepreneurship.

CASE STUDY

African Drone & Data Academy

The African Drone and Data Academy is a UNICEF-sponsored program operated by Virginia Tech in partnership with the Malawi University of Science and Technology. Created in response to the lack of technology skills experienced by local drone companies, the program was first launched in January 2020 with its first campus located in Lilongwe, Malawi to provide young entrepreneurs and undergraduates students with technology education.

As of 2023, the academy has covered 28 countries, 932 graduates across 6 courses, opening to students from all over Africa. The courses are offered both online and in person, covering topics from drone logistics and planning to data visualisation and cartography and provides certification upon completion. This program facilitated the uptake of drone technologies in Africa. Graduates from the African Drone and Data Academy has been recruited by leading drone companies in the region (Swoop Aero) as well as established their own drone company (Nkwazi Aeros).

Figure 36. African Drone & Data Academy

Source: Feed the Future Flickr. Photo credit: RTI International

Source: Feed the Future Flickr. Photo credit: SUDIPTO DAS

Deploying hardware in low-resource, rural settings present its unique challenges. These environments are often exposed to extreme elements, making hardware operation a significant challenge. An emerging gap in this area is the increased focus on preventative maintenance, acknowledging that robust upkeep of such systems is as important as their initial deployment.

Furthermore, the concept of mechanization is shifting. For many use cases, basic mechanization—such as tractors and associated equipment—should be viewed as a prerequisite or a "force multiplier" for digital tools, rather than a supplement or something to be "leapfrogged." Our interviewees have often voiced a concern about D4Ag startups focusing mostly on precision farming technologies, while leaving simple mechanization to the agribusiness space. The topic of access to mechanization hardware is specifically acute for sub-Saharan Africa, where it was estimated that in 2015 in Central Africa 80% of cultivated land was worked manually while in Eastern and Southern Africa, that figure stood at about 50%.[35]

Mechanization holds the potential to enhance the cost- and scale-efficiency of hardware. This enhancement can be achieved by improving the actionability of advisories and practice changes, ensuring that individual units of hardware go "further," and by creating opportunities for automated data collection and feedback loops, for example, leveraging "as applied" data. Therefore, a holistic approach to D4Ag should view hardware not as a standalone solution but as an integral part of a broader interconnected ecosystem, where maintenance, mechanization, and data integration play crucial roles.

[35] Is muscle or machine the future of agriculture in Africa? (worldbank.org)

Physical Infrastructure

Overall, internet connectivity, data affordability, and device ownership still remain as barriers for impactful D4Ag adoption among smallholder farmers in most LMICs: Globally, 50% of population in LMICs is still not using mobile internet, with the rural-urban gap reaching 33%.[36] Smartphone adoption rate in emerging markets now stands at around 37%,[37] and only 24%–37% of farms under one hectare in size are served by 3G or 4G services.[38] While overall affordability can be high in general according to international standards, applying this to smallholder farmers is misleading, as data may still be unaffordable for those without a constant stream of income. The following table summarizes the level of maturity for internet, data, and mobile phone access in each region, based on country-level statistics.

	Internet coverage (% of total population)			Data affordability	Device affordability
	using mobile internet	not using mob. Internet	not covered by mobile broadband	median price of 1 GB**	median cost of the cheapest Internet-enabled phone**
South Asia	41%	54%	5%	0.5%	22.6%
Southeast Asia*	68%	30%	2%	1.8%	18.2%
Sub-Saharan Africa	22%	61%	17%	3.4%	25.2%
Latin America and the Caribbean	62%	35%	3%	1.7%	9.7%

*Including the Pacific
** As % of monthly GDP per capita

Table 9. State of Mobile Connectivity in LMICs[39]

Sub-Saharan Africa's progress is lagging compared to other LMIC regions. For example, sub-Saharan Africa is still served mostly by 2G and 3G services, while other regions have implemented 4G. The penetration of 4G services is respectively 48% and 47% for Latin America and the Caribbeans and Asia (South and Southeast Asia) in 2019, but only 10% for sub-Saharan Africa.[40]

Higher cost of airtime, data, and devices reduces internet connectivity and mobile penetration; for example, based on a survey conducted in Kenya, 53% out of around 1,000 surveyed cite not having a phone as the reason for being unable to access the internet. Therefore, to improve the state of digital infrastructure, it is important to simultaneously reduce the cost of and improve access to both connectivity and device ownership.

[36] GSMA The State of Mobile Internet Connectivity, 2022
[37] Accelerating Affordable Smartphone Ownership in Emerging Markets, GSMA, 2017
[38] Mehrabi, Z.; McDowell, M.J.; Ricciardi, V.; Levers, C.; Martinez, J.D.; Mehrabi, N.; Wittman, H.; Ramankutty, N.; Jarvis, A. (2020) The global divide in data-driven farming. Nature Sustainability, Online first paper (02 November 2020) ISSN: 2398-9629
[39] The State of Mobile Internet Connectivity 2022, GSMA
[40] GSMA Digital Agriculture Map, 2020

"The reality is that most farmers in Ghana do not have even a basic feature phone. However, I do not believe we should keep providing farmers with phones. How about instead we ensure that farmers are paid fairly and equitably? Are we doing that? In my country the answer is no. So, they are stuck in poverty and cannot afford even a simple phone, that is the reality."

AgTech Innovator, sub-Saharan Africa

Besides digital, the physical connectivity networks also often fail to support reach and adoption of D4Ag: commonly lacking cold supply chain infrastructure, warehousing, and even roads all create additional barriers for D4Ag innovators in LMICs.

"We have complexities that no one is talking about. People get excited about the agenda of AgTech, but I don't see how it's possible to run an AgTech business in the part of the world without infrastructure, and the government is not talking about it. It is definitely nice to sit in an office and excitedly talk about AgriTech, but when you are in the field and the reality sets in, it is just very different."

AgTech Innovator, sub-Saharan Africa

Source: Feed the Future Flickr. Photo credit: Faisal Hossain

Chapter IV:

Funding and Investment Landscape

When discussing D4Ag funding and investment in this chapter, we are specifically focusing on capital deployed to enhance the growth of D4Ag solutions, rather than infrastructure or other peripheral aspects. This funding serves as the lifeblood of the sector, offering businesses the essential resources to invest in expansion, innovation, and reaching new markets.

While venture capital (VC) often steals the spotlight in discussions around investment, the funding landscape for D4Ag is far more diverse. Beyond VC, it includes various classes of investment, such as government budgets, multilateral investments, NGOs, foundations, and more. This broader bucket reflects the multidimensional nature of D4Ag and the need for different types of capital to fuel different stages and aspects of growth.

Commercial and sub-commercial funding typically comes from investors seeking a return on their investment, such as angel investors, impact investors, venture capitalists, corporate investors, and private equity firms. Grants, on the other hand, are typically non-dilutive funds provided by entities such as foundations, government agencies, and NGOs to achieve specific social, economic, or environmental goals. Grants are particularly important in the early stages of a startup when risks are higher, and the business model may not be fully established. However, overreliance on grant funding poses significant risks, including the uncertainty of continual funding, the administrative burden of grant reporting, and the potential for mission drift due to donor priorities.

Despite its importance, the data around D4Ag investment is relatively opaque. Historically, there has not been a single comprehensive source, especially one that provides a detailed view of deal-flow data in the D4Ag sector in LMICs. While information might be more accessible in areas like venture capital or private equity, trying to extract specific data related to "digital" AgTech becomes complex, as most reports focus on overall AgTech investments. Furthermore, data on early-stage, grant-funded or bootstrapped solutions is often difficult to find. These data gaps make it difficult to fully understand the nuances of funding in the sector. The newly launched AgBase initiative and associated business intelligence platform will attempt to close these gaps, providing up-to-date information on innovators, investors, and deal-flow with a prescriptive focus on the D4Ag sector in LMICs.

Source: Tepbac

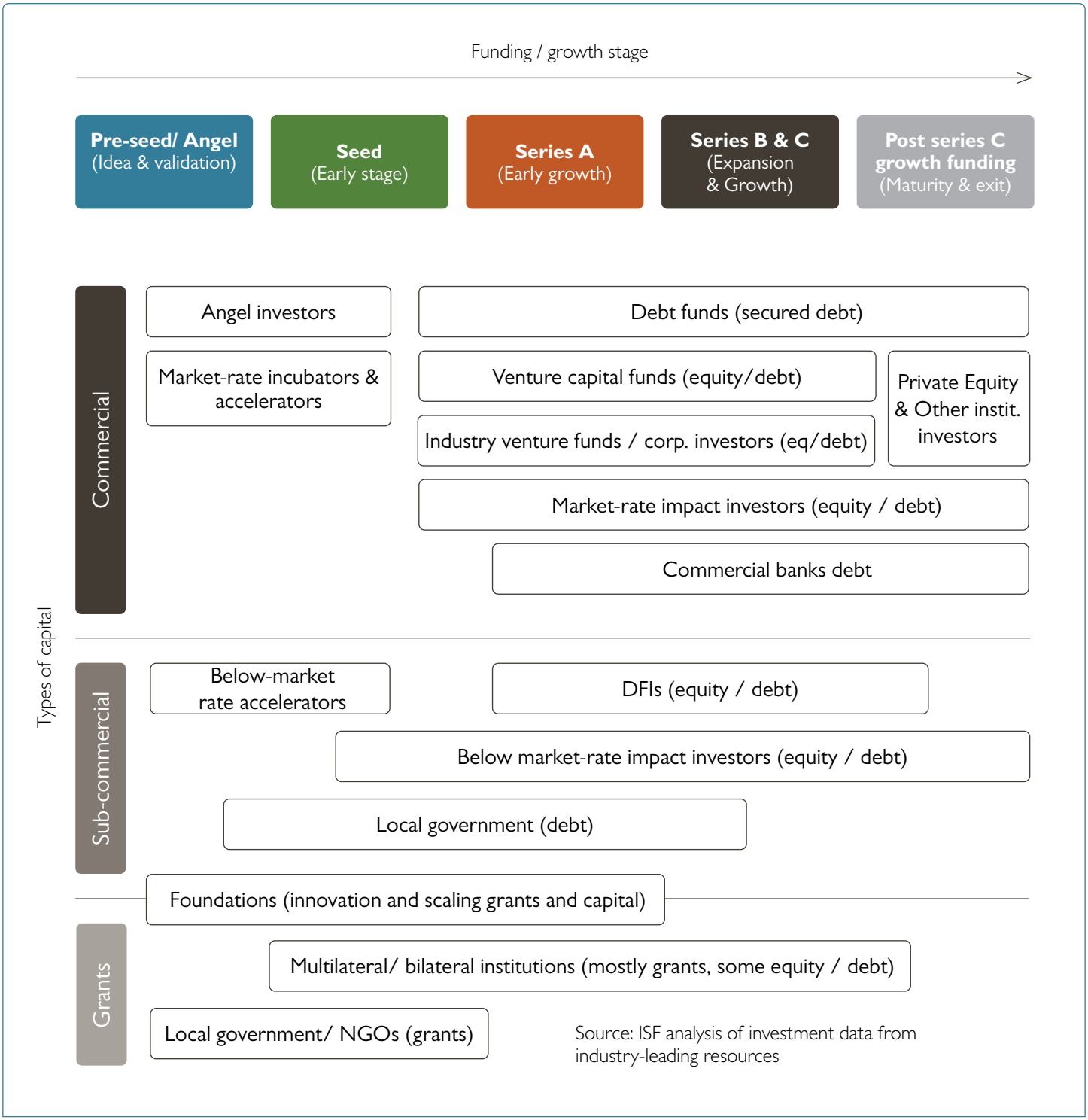


Figure 37. Key Funder Sub-Segments in D4ag. Source: ISF Advisors

Launch of AgBase Initiative

As noted above, many key challenges in the D4Ag ecosystem result from lack of funding, lack of data and insight sharing, and lack of collaboration amongst stakeholders. To address these challenges and build on the recommendations outlined in this report, the Bill & Melinda Gates Foundation, and USAID have collaborated to launch AgBase, an ecosystem-building initiative for the D4Ag sector. The AgBase initiative will center around a business intelligence platform that connects investors and innovators to data, research, and market insights in order to fuel thriving FoodTech and AgTech ecosystems in LMICs. In addition, AgBase will aim to showcase impact data and promote sector collaboration. AgBase will be jointly implemented by Mercy Corps and Briter Bridges, and supported by a wide variety of industry-leading partners, such as AgFunder.

Figure 38. Lauch of AgBase Initiative

The current global economic situation poses both opportunities and challenges for D4Ag investment. A coordinated effort by various funders is vital to circumvent potential stagnation or reversal in growth, especially in the face of economic uncertainties.

The current global economic situation poses both opportunities and challenges for D4Ag investment. In addition to increased data transparency, a coordinated effort by various funders is vital to circumvent potential stagnation or reversal in growth, especially in the face of economic uncertainties. As part of the broader ecosystem building initiative, AgBase will aim to promote collaboration among funders and other industry-leading stakeholders through the establishment of sector-level goals and a coordinated learning agenda.

Despite these gaps and broader economic challenges, there is a clear trend that the D4Ag sector has been attracting increasingly significant amounts of capital in recent years, with a growing proportion being deployed in LMICs. Increasing supply of innovations, maturing infrastructure and financial markets in some LMICs, as well as policy support all lead to an increase in investors' interest in the sector. Besides, growing attention to climate change and convergence of AgTech with ClimateTech has been attracting investors from these intersecting areas. Simultaneously, generalist investors like Softbank & Sequoia leading **eFishery**'s Series C, Tiger Global Management and Alpha Wave Global investing into Indian **Absolute Foods**, or Google Impact Assets supporting **CropIn** at pre-Series D, all have shown interest in the sector, contributing to its capital growth.

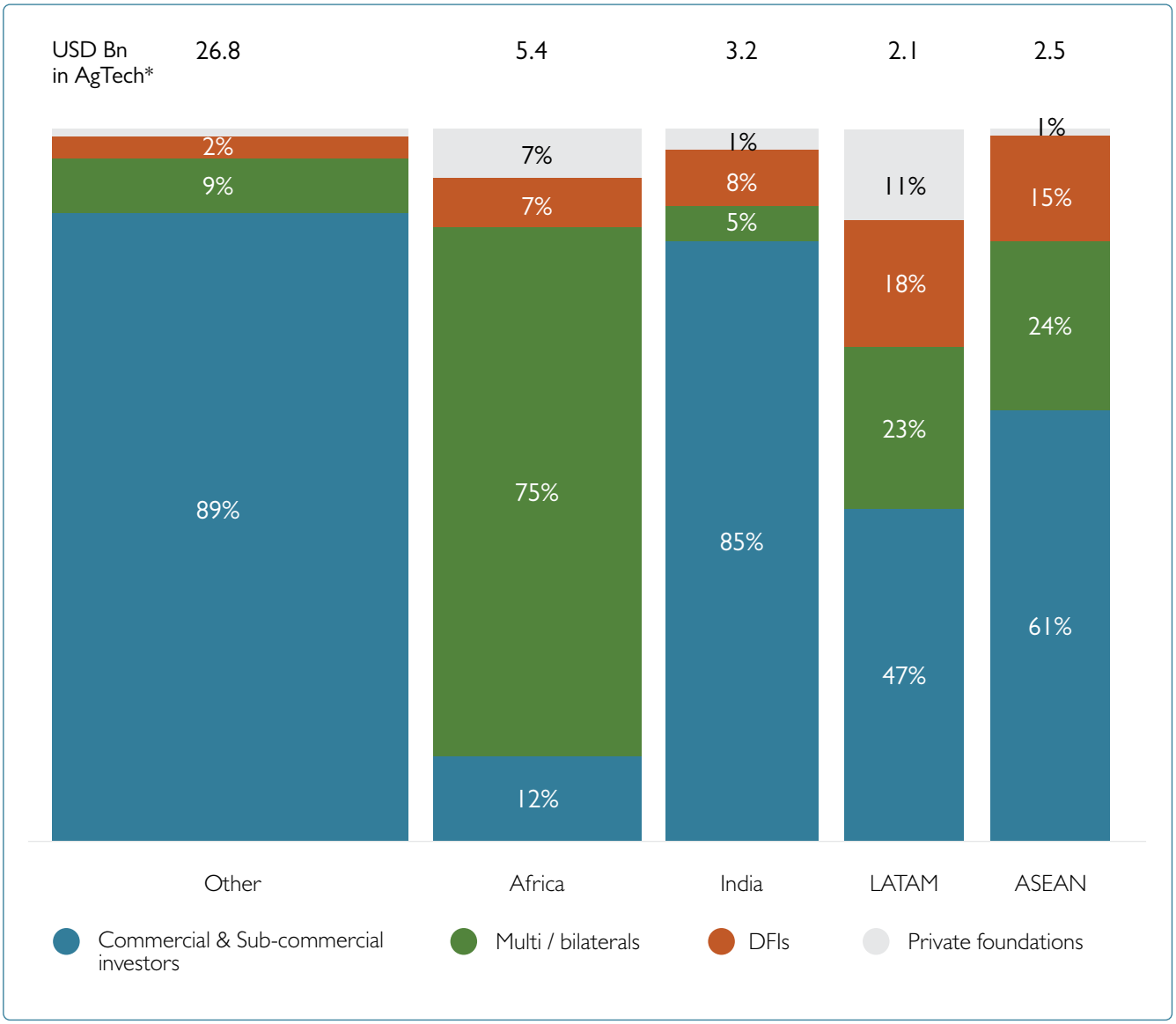


Figure 39. Types Of Capital in AgTech. Source: ISF Advisors

Cumulatively to date, global AgTech innovators (including non-digital) have amassed a significant US$40 billion in total funding of all types (with US$13.2 billion allocated to LMICs), with 14% channeled to Africa (including North Africa), 8% to India, 6% to ASEAN, and 5% to Latin America.

A geographical examination of investments reveals that among the developing regions, Africa and South Asia are leading the way, however with drastically different capital sources. Within Africa's AgTech sector, the majority (75%) of investments are donor-driven, making the region the largest receiver of donor funding. Contrastingly, India exhibits a robust commercial investment climate, where 85% of funding derives from commercial and sub-commercial investors.

Commercial Capital in D4Ag

Private investors typically seek scalable business models with a clear path to profitability, a large total addressable market (TAM), and strong founding teams. However, there are well-established structural challenges to scalability and time-to-market for D4Ag relative to

other tech sectors, such as longer product development and sales cycles, seasonality, external stressors, cash-on-hand constraints for the user base, and fragmentation of demand. Generalist investors, with their significant capital contributions, typically lean toward familiar business models such as enterprise Software as a Service (SaaS) and FinTech, which are known to provide reliable returns on investment. In contrast, the D4Ag space presents a different set of challenges that can impact the return on investment. These challenges are especially apparent when solutions are tailored to local contexts, geographical differences, and specific stakeholder needs—often characterized by high-touch solutions which may require more effort to deploy and achieve a successful impact. This tailored approach might struggle to achieve the economies of scale that investors are looking for, thereby limiting the attractiveness of these solutions to generalist investors.

Investors in Latin America, for instance, are seeking opportunities beyond revenue-per-hectare models that might cap their potential value. The idea here is that traditional agricultural metrics, like revenue per hectare, may not fully capture the multifaceted value generated by D4Ag solutions, such as improved sustainability or resilience. Thus, it is essential for D4Ag innovators to articulate their value proposition in a way that appeals to the broader interests of investors, beyond traditional agriculture metrics.

In 2021, D4Ag innovators in LMICs raised approximately US$2.5 billion from private investors. The bulk of investment deals remain in their infancy, with India emerging as a frontrunner in later-stage, post-Series B investments.

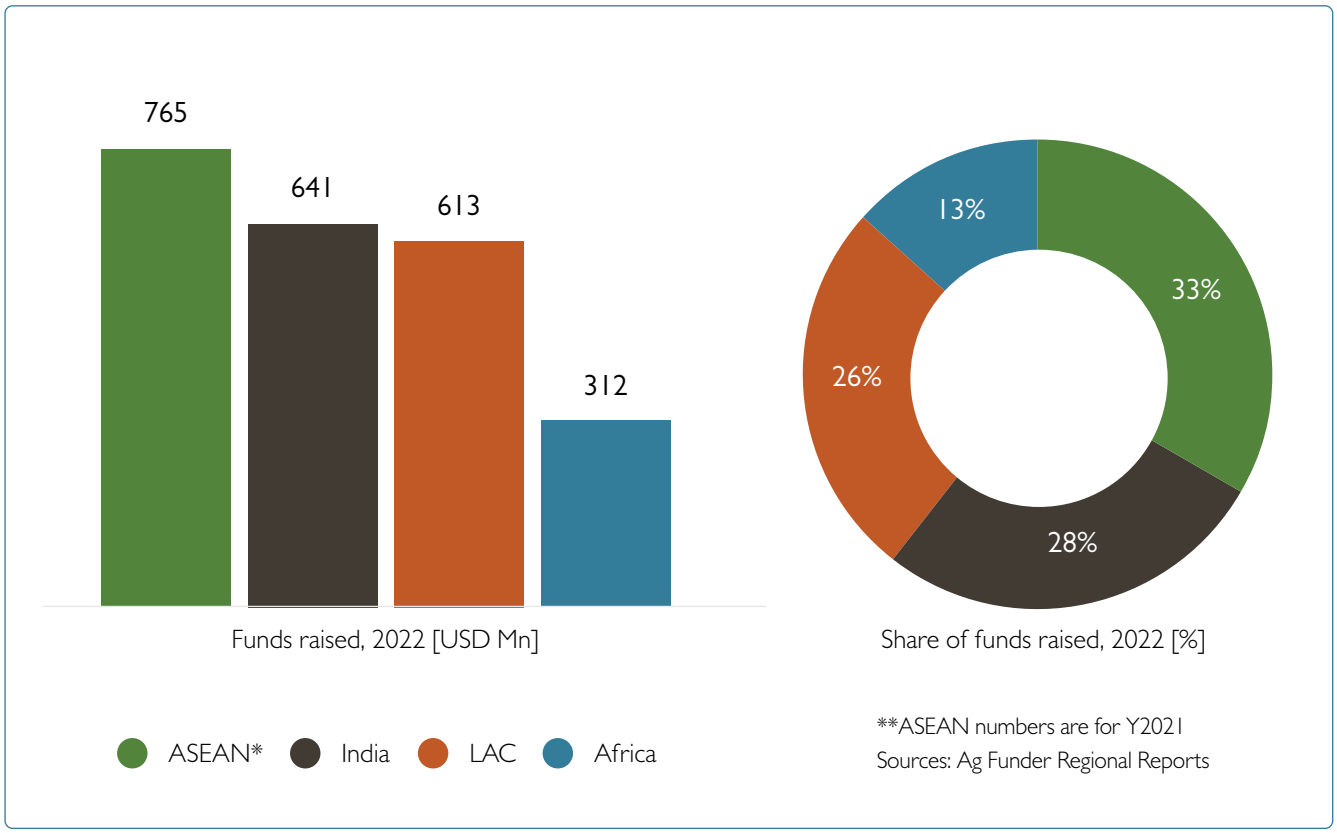


Figure 40. Private Capital Raised by D4Ag Innovators in LMICs (2022)

Private capital for the sector remains heavily concentrated across several key factors: geography, use case, value chain, and even specific companies. Geographically, private funding is majorly focused on a few countries like India, Brazil, Kenya, Nigeria, Singapore, Indonesia. These nations have emerged as regional "powerhouses" of technological innovation, reflecting trends observed in other sectors. While there have been significant investments in other regions, they are typically one-off occurrences rather than showcasing a consistent trend. Some regional specificity reflects local value chains (for instance, aquatech in Indonesia), favorable policy environments (such as AgriFinTech in India), and the broader development of agricultural systems.

Sub-Saharan African markets remain least attractive to private investors, as D4Ag innovators there raised around US$312 million in funding from private investors in 2022. India, on the other side, has emerged as a global leader in D4Ag, with Indian innovators securing almost 30% of all private investments into the sector in 2022.

Source: Feed the Future Flickr. Photo credit: Alanuzzaman Kurishi

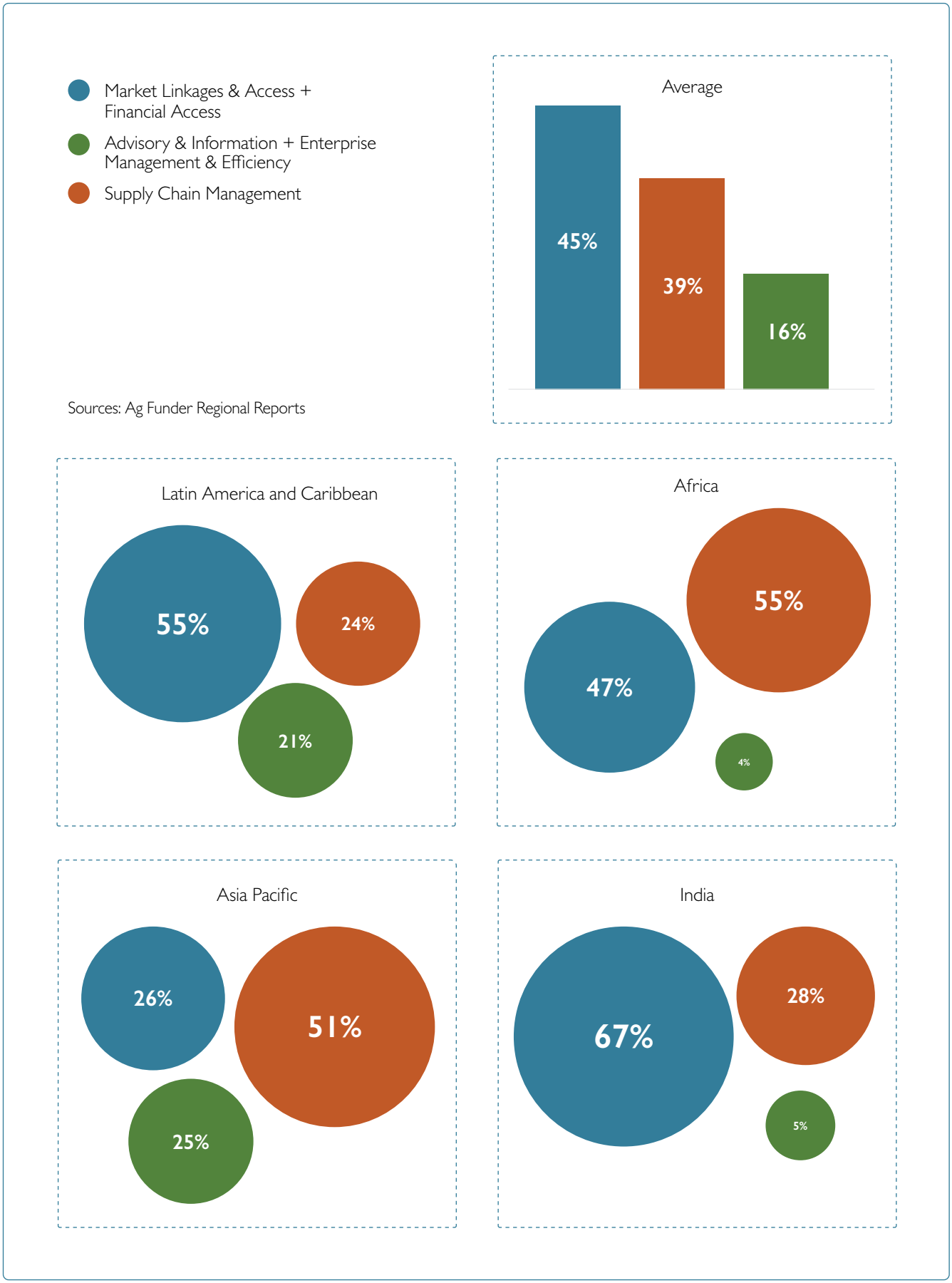


Figure 41. D4Ag Investment by Category & Region, 2022

Technologically, Market Linkages & Access are garnering the majority of investments. This trend underlines the appeal of software-centric, asset-light business models for digital platforms that simplify and amplify market access for agricultural producers and businesses. Supply chain management tools trail closely behind, showing investors' appetite to solutions enhancing various facets of the agricultural supply chain.

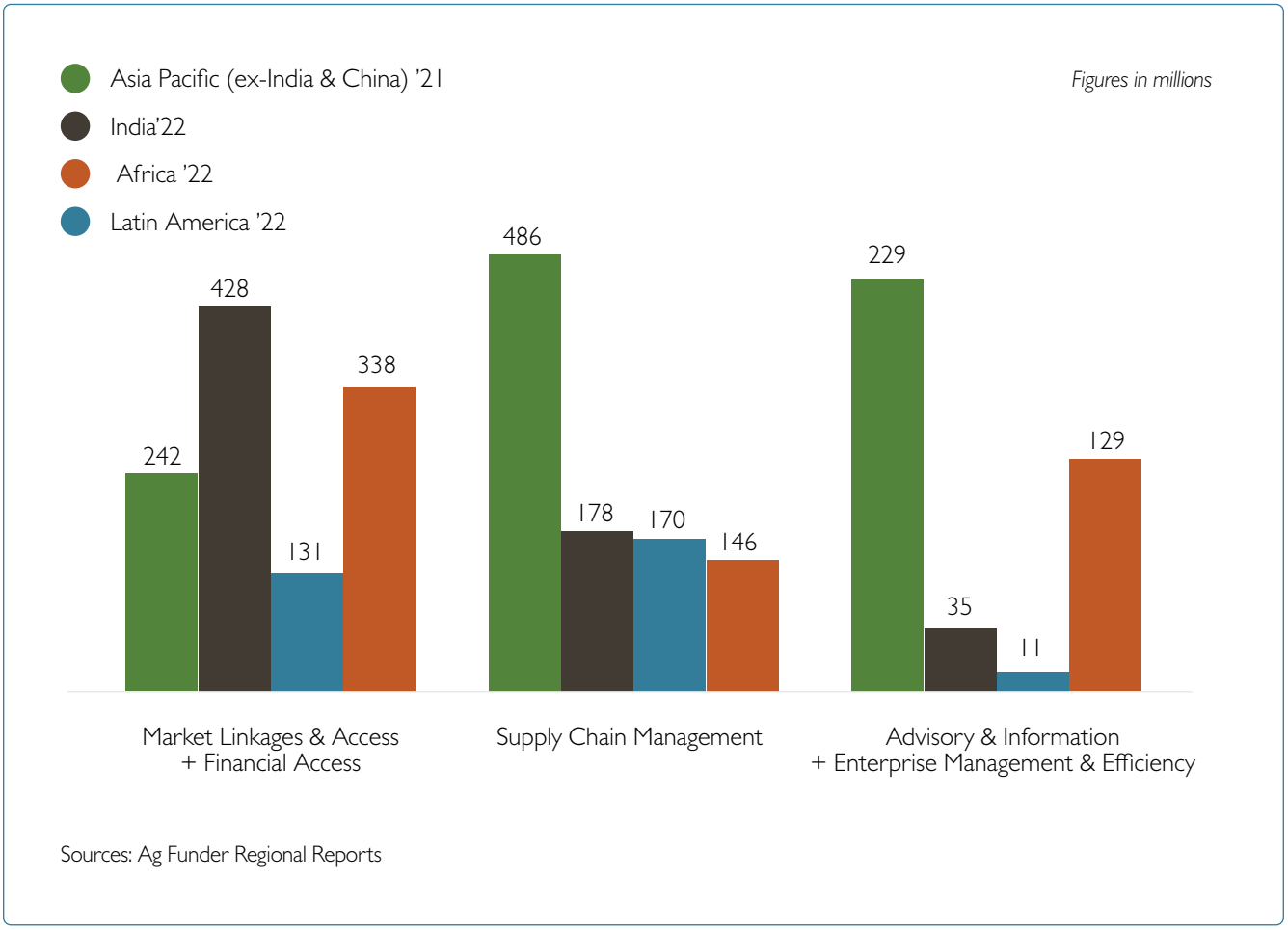


Figure 42. D4Ag Investment By Category & Region, 2022

The majority of early-stage D4Ag funding has concentrated on Market Linkages & Access (input and output agri marketplaces) and Financial Access tools. These areas tend to attract more funding as they are perceived to be easier to scale and investors are more familiar with these models from other tech sectors, such as e-commerce and fintech. However, the venture investability of other D4Ag use cases remains an open question, as they still struggle with demonstrating to investors that these alternative D4Ag models can be both scalable and profitable.

A considerable portion of D4Ag solutions identified have been bootstrapped, i.e., self-funded or funded through revenues. This highlights the entrepreneurial spirit and resilience in the sector but also underlines the challenges many startups face in securing external investment.

In terms of successful exits in the D4Ag space, they remain relatively rare and concentrated in specific areas, and most of the successful exits have been through strategic buyouts or mergers and acquisitions (M&As) rather than initial public offerings (IPOs).

"The entire AgriTech exit landscape has been pretty limited in the last few years, there aren't many success stories. And another big challenge is that the agricultural cycles are much longer: if you develop a software solution, you can test it within days. In agriculture it has to do with farming operations, so you have one season. If you missed the season, you need to wait till the next year. So, the ability to do iterations is limited, limiting the growth potential of AgriTech startups. Therefore, for AgriTech, the investment horizons are indeed longer than for other sectors. And at this point most of the potential exits will come from strategic sales and not from IPOs, which again, also limits the potential."

AgTech Investor, South Asia

	Eruvaka	Neura-farms.ai	Allfresh	Heli-crofter	PanenID	BoosterA-gro	Brain.ag	Freshmart
Country	India	India	India	India	Indonesia	Argentina	Brazil	Peru
Founded	2013	2021	2013	2020	2017	2016	2019	2016
Exited	2022	2022	2022	2022	2022	2021	2021	2021
Exit Type	M&A	M&A	M&A	M&A	M&A	M&A	M&A	M&A
Buyer	Nutreco	AiDash	Waycool	DeHaat	Glife Technologies	Agrosmart	Serasa Experian	Justo

Table 10. Snapshot of the Latest D4Ag Exit Rounds

Most strategic exits are anticipated in product- or deep-tech-based solutions. These solutions often provide novel approaches to long-standing agricultural challenges, making them attractive to larger firms seeking to enhance their product offerings or gain a competitive advantage. However, the market for late-stage D4Ag investment is less established than for early-stage ventures, presenting an additional challenge for D4Ag startups looking to scale, as they may struggle to secure the necessary funding to fuel their growth at later stages.

Several other forms of capital are gaining importance in fostering a diverse, impact-oriented D4Ag ecosystem. Working capital and short-term debt stand out as high-need areas for financing that are generally underdeveloped and inaccessible to D4Ag solution providers in LMICs. High interest rates and stringent collateral requirements are notable barriers limiting access to credit for innovators. This presents an opportunity for blended capital and credit guarantee schemes to bridge the gap.

"So biggest challenge for an entrepreneur, and where I have a serious issue for my portfolio companies, is working capital support. They're doing great, but it's difficult for them to really get working capital support. So, if like a donors can give a FDG guarantee of 5- 10 percentage, and I can leverage it to 10 times, that would bring more organized credit in the hands of the innovators, right? Which means people who are getting exploited by money lenders on unorganized money lending ecosystem can be reduced."

AgTech Investor, South Asia

Another challenge lies in the "missing middle" of investment—between small-scale grants (less than US$50,000) and the average ticket size for African AgTech innovators (over US$750,000). This missing class of investment creates a funding gap for startups in need of seed financing. Given the lack of visibility into early-stage grant-funded solutions, additional data on these players will be instrumental in closing this gap. Anecdotally, in Madagascar, for example, local VCs often have a minimum investment threshold of US$50,000, which is significantly more than a local startup requires for seed funding. This gap can be filled in by the acceleration capital—post incubators, but pre-VC—often missing in LMICs.

Source: Feed the Future Flickr. Photo Credit: Karin Higgins.

> *"The number of funds is there, but there is a middle gap, the missing middle, which exists. When you are small, you attract grants easily, but the more the business grows, but you have not yet reached the point of attracting huge private capital, and the grants no longer apply. You are caught up in the middle. This missing middle kind of financing is a huge gap across Africa. Existing funds need to be restructured to cater for it. When you talk to private investors, they want growth over time, growth of your margins, reduction of costs, growing your business, or scaling geographically in different markets. But if I don't have money, we can't do those kinds of things. Then you come to the grant providers, they want you to target refugees or people who live below US$1 per day. But solely these guys can't be my customers at this stage. You're caught up in the middle and you're like, where can I get the money?"*
>
> AgTech Innovator, sub-Saharan Africa

Incubators and accelerators can play a critical role by providing unique models of capacity building and strategic advisory for founding teams navigating this transitional period. Involvement at this earliest stage of fundraising could have a particularly significant impact. It would help innovators retain long-term equity, a point raised particularly in Latin America, where early investors often take a relatively large stake, creating challenges for long-term startup viability.

Sub-Saharan Africa	Latin America and the Caribbean	South Asia	Southeast Asia	Global (operating in LMICs)
• The Baobab Network • Founders Factory Africa • GrowthAfrica • Opolo Global • Kosmos Innovation Center (KIC) • Ghana Climate Innovation Center (GCIC) • aGri Innovation Hub	• Brazil's Pulse Innovation Hub • ACE Ventures • The Yield Lab LATAM • Wayra	• CIIE.CO • Villgro • Pusha Krishi • ThinkAg • NICL Pakistan • Acumen Pakistan Agriculture Accelerator	• GROW • SKALA • Tinc • Nest Thailand	• Thought For Food (TFF) Challenge • Techstars Farm to Fork Accelerator • Plug & Play • SOSV • FoodFutureCo • 500 startups • Village Capital • Katapult Accelerator

Table 11. List of accelerators offering AgTech programs in LMICs

Donor Organizations and Development Agencies in the D4Ag Sector

There has been a lot of activity in the sector from donor organizations and development agencies, who have the potential to contribute to the impactful and inclusive growth of the sector. However, our interviewees mentioned several challenges that must be addressed to ensure their involvement becomes a catalyst rather than a distortion in the market.

Selective Funding: When donors select certain projects or specific innovators to fund, it may inadvertently lead to an uneven playing field. Those not selected, may struggle more due to lack of support. Sustaining otherwise unsustainable business models often distorts competition and reduces traction for those innovators with more viable business models. Furthermore, development agency teams often do have the necessary skills for effective due diligence, which may result in selecting recipients based on factors other than potential success (like personality of founders or proposal writing skills).

Mission Drift: We have also observed and heard our interviewees report some examples of structural disconnect between grants provided to D4Ag innovators and their actual commercial needs. The impact orientation of grants does not always align with investment readiness and the needs of business models. To help bridge this divide, angel networks are becoming more prevalent and proactive across LMICs. While these networks are typically generalist, they are seeking ways to support and become more involved in the D4Ag sector.

> *"Right now we do have a lot of projects with different donors from the EU and the US. The problem is that these projects, sometimes they are not really helping us, because they are not focusing on our strategic plan and mission. They have a specific goal in mind, and money comes with the agenda that follows this money, and they are not willing to fund a project that, in reality, would be more impactful."*
>
> AgTech Accelerator, sub-Saharan Africa

Commitment and Continuity: Donors often operate within a set time frame, which may not always align with the needs of the D4Ag sector. This can result in partially completed projects and compromised relationships. Our interviewees clearly expressed a need for more outcome- or process-bound programs, which can adapt to the timelines and challenges of the D4Ag sector.

Adding Value Beyond Funding: There are many opportunities for development agencies and donors to create value beyond just funding. They can leverage their networks to provide referrals, offer publicly accessible market intelligence, provide technical and administrative support to innovators, and use their influence to foster favorable policy environments. Donor organizations, in collaboration with public sector actors, can contribute significantly toward the development of common good infrastructure, both physical and digital. This can serve as a catalyst for the growth of the D4Ag sector and ensure that its benefits are accessible to all stakeholders in the ecosystem.

These challenges highlight the need for donors to continually reassess their approaches and strategies, to ensure their contributions effectively support the growth and sustainability of the D4Ag sector.

> *"D4Ag startups need more than one-time funding or competition prizes. It's crucial to focus on continual capacity enhancement, ongoing learning, and exposure. Startups need meaningful interactions with stakeholders and technical support throughout their journey. It's not purely about money but about fostering enduring growth and progress."*
>
> D4Ag Innovator, sub-Saharan Africa

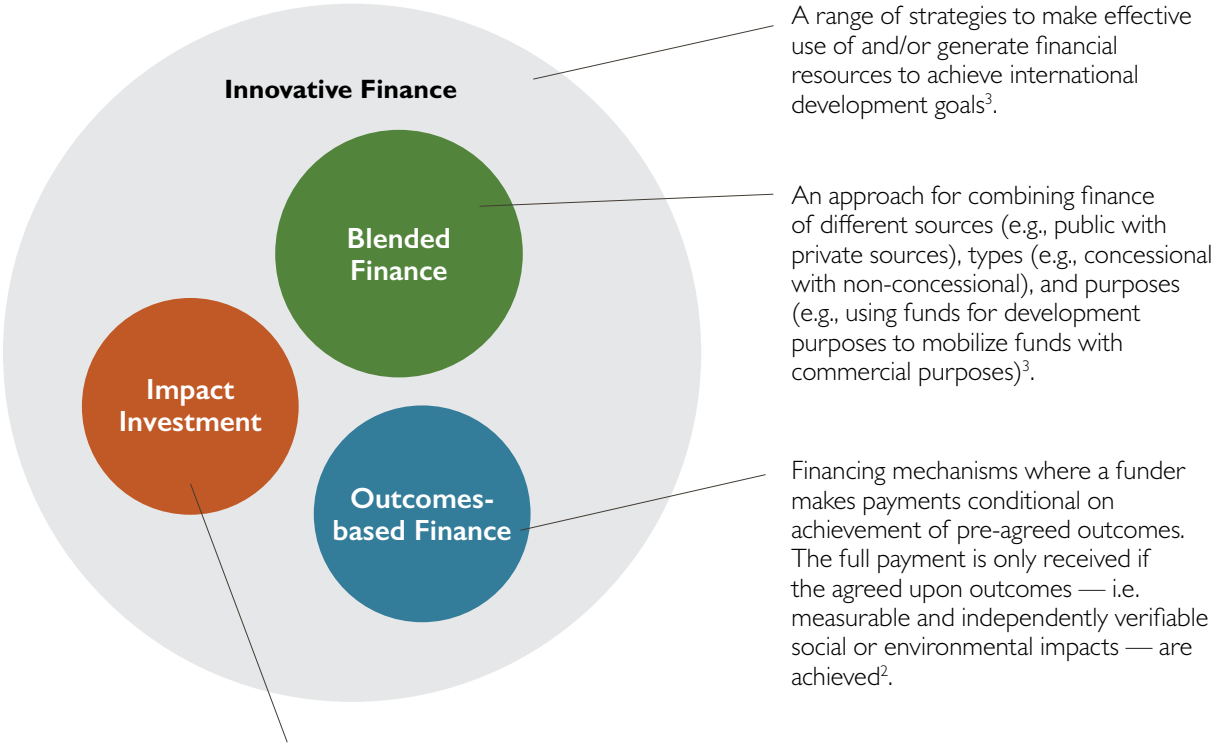
The Need for Patient Capital and Alternative Funding Approaches in D4Ag

In the face of a global economic downturn, it becomes even more important to emphasize the need for "patient" capital and alternative funding approaches to support the continued growth and viability of the D4Ag sector. Blended finance structures are emerging as an innovative approach to leverage the strengths of both grants and commercial capital.

> *"Blended finance works well for any impact investments where there is a high perceived high risk. So, if you want to attract private investors into a sector that is perceived high risk, I think blended finance is the answer. […] Our total fund is EUR 120 million, where 20 million is a very cheap debt from the Spanish government. We got 10 million euros of first loss. With these 10 million euros of first loss, we got 90 million euros of private capital, and we raised it very quickly as well. If it is built in the right way, which means you need to have sufficient first loss to address that kind of risk perception, and if all the stakeholders in a blended finance vehicle are aligned, I think it can be very powerful. Among investors for sure there is a perception that agriculture is risky. So I think blended finance is good, it's certainly great to attract private capital to the table."*
>
> Impact investor, Global

RETHINKING FINANCE: OVERVIEW OF INNOVATIVE FINANCE MODELS

"Sustainable agriculture is a particularly relevant target for blended fi nance given its signifi cant GDP contribution in many countries, and the need to overcome barriers such as the remote location of counterparties, lack of information, and high opportunity costs. Interesting entry points may be found through novel partnerships, for example with agribusinesses, government agencies, technology companies, private capital providers, and NGOs" (Haveman, 2020).



Sources: 1) Global Impact Investing Network; 2) The World Bank; 3) Blended Finance: When to use which instrument? University of Zurich, 2022

Blended finance models in agriculture can be deployed via a myriad of financial instruments, such as grant funding (e.g. for technical assistance) as well as concessionary versions of existing financial instruments including concessionary debt (i.e. debt provided at softer terms such as longer grace periods and lower interest rates), risk absorbing equity, and subsidized guarantees and insurance mechanisms.

Figure 43. Overview of Innovative Funding Models [41] [42]

[41] OECD. Blended Finance & Impact: Guidance and Principles

[42] Havemann, T., Negra, C. & Werneck, F. Blended finance for agriculture: exploring the constraints and possibilities of combining financial instruments for sustainable transitions. *Agric Hum Values* **37**, 1281–1292 (2020). https://doi.org/10.1007/s10460-020-10131-8

Donors	Public sector	Private Investors
Africa Agriculture and Trade Investment Fund (AATIF) is a US$146 million investment fund created by BMZ (a German donor agency) and banks (Deutsche Bank, KFW). Public donors took "first loss" junior equity positions (63% of the fund) which allowed commercial investors to take more favorable senior equity positions with higher risk-adjusted returns.	**The Nigeria Incentive-Based Risk Sharing System for Agricultural Lending (NIRSAL)** is a US$500 million NBFI under the Central Bank of Nigeria combines US$300M risk sharing, US$30M insurance, US$60M technical assistance, US$10M credit rating, and US$100M outcome-based funding.	**GAWA's Capital EUR120 million Huruma Fund** has the support of the AECID (Spanish Agency for International Development Cooperation) and European Union, who reduce the risk for private investors: EU provided a EUR10 million first-loss guarantee, AECID offers EUR20 million subordinated debt, while private investors allocated EUR90 million.

Figure 43. Overview of Innovative Funding Models

Indeed, the current economic climate poses challenges but also presents opportunities for innovative solutions and new forms of investment. With astute planning and strategic investment, the D4Ag sector can continue to flourish, even amid a downturn. Patient capital, guarantee funds, and other alternative funding models can play a crucial role in buttressing the sector, especially for startups that find themselves in financial straits.

Source: Feed the Future Flickr. Photo credit: Moustapha Gabar Diop (Nafoore Warsaaji Communication Specialist)

Chapter V:

Impact of D4Ag

OVERVIEW OF KEY FINDINGS ABOUT THE IMPACT OF D4AG

The potential of D4Ag to bring about substantial transformation across the agriculture value chains in LMICs is vast. Its theorized and observed impact has been identified across various dimensions of utility, broadly falling into three buckets: economic, social, and environmental impact.

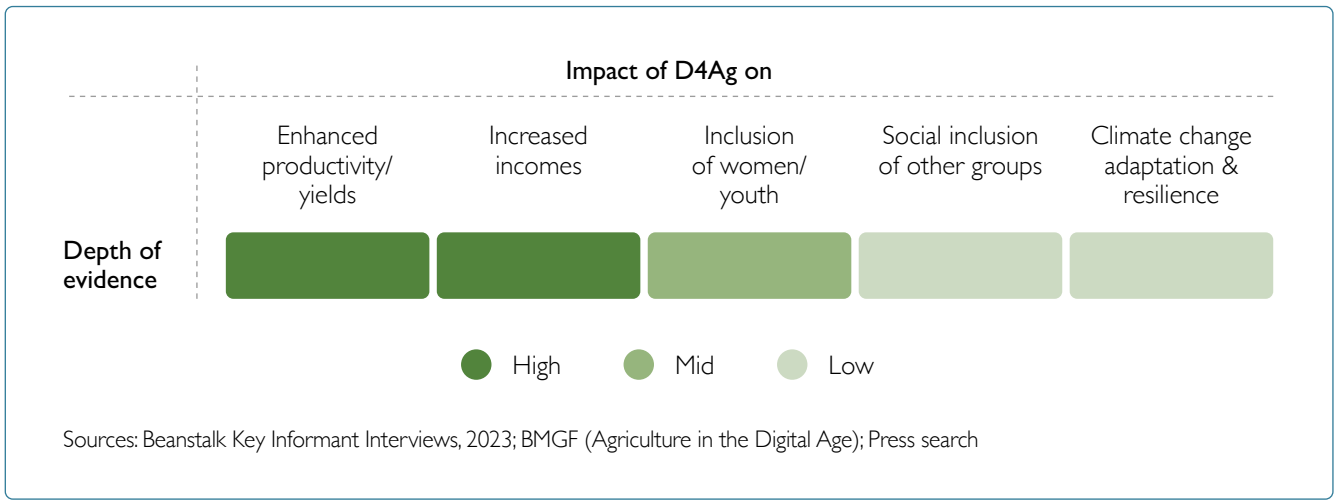


Figure 44. Impact Evidence Map: Looking Across Economic, Social, And Environmental Dimensions Of Impact

Economic Impact:

D4Ag has the potential to significantly enhance agricultural productivity, increase farmers' income, and improve market efficiency. It does this by offering farmers access to timely and actionable information, improving their ability to make data-driven decisions. For instance, using weather forecasts and crop health data, farmers can optimize their planting and harvesting cycles, leading to improved yields. Additionally, digital marketplaces connect farmers directly with buyers, reducing the need for middlemen, and thus potentially increasing the farmers' share of the end consumer price.

Social Impact:

D4Ag can contribute to the empowerment of marginalized groups, such as women and rural communities. By providing them with access to resources, information, and markets, these technologies can help reduce socioeconomic disparities. D4Ag can also promote knowledge sharing and foster a sense of community among farmers through digital platforms. Furthermore, the use of digital tools can facilitate improved health outcomes by supporting better nutrition through crop diversification and efficient delivery of farm produce to markets.

Environmental Impact:

The adoption of D4Ag can lead to more sustainable farming practices and better natural resource management. Precision farming technologies allow farmers to use water, fertilizers, and pesticides more efficiently, reducing waste and environmental pollution. Furthermore, D4Ag can facilitate the transition toward climate-smart agricultural practices, by providing farmers with information on sustainable practices and weather patterns. Satellite imagery and data analytics can also assist in monitoring environmental changes and biodiversity, contributing to conservation efforts.

Economic Outcomes	Social Outcomes	Environmental Outcomes
Income: Change in income **Productivity/ Yield:** Change in on-farm crop, laborer livestock productivity **Market Efficiency:** Change in decision-making based on available, relevant market information **Cost Effectiveness:** Decreased costs of production **Employment:** Job creation in rural areas	**Gender Inclusion:** Increase in influence, decision-making or agency **Social Inclusion:** Reduce or remove the obstacles that limit the agency, decision-making capacity **Nutrition:** Improved household nutrition, including increased food supply and security	**Climate Resilience:** Prevention or minimizing the impacts of climate change **Environmental Sustainability:** Improved sustainability of natural resource management, such as water, forest or soil management

Table 12. Potential Impacts of D4Ag

Despite the growing adoption of D4Ag in LMICs, we have a limited understanding of the factors that drive the impact of D4Ag, both positive and negative. "The Digitalisation of African Agriculture Report 2018–2019" and subsequent studies have exposed a significant gap in the evidence regarding D4Ag's impact. The existing evidence primarily focuses on a subset of low- and middle-income countries (LMICs) and specific commodities, with an emphasis on economic outcomes. The gap between the claimed and actual impact of D4Ag innovations remains vast and unexplored, underscoring the potential disconnect between what D4Ag technologies promise and what they deliver on the ground. This discrepancy may lead to misallocation of resources, misplaced priorities, and the potential disillusionment of stakeholders, including farmers, investors, and policymakers. It may also hinder the adoption of beneficial technologies, as exaggerated or inaccurate claims can erode trust in new solutions. Ultimately, understanding and addressing this gap is essential for ensuring that investments in D4Ag are directed toward truly effective and impactful solutions that can contribute to sustainable agricultural development, particularly in low- and middle-income countries.

One of the latest and largest attempts to identify evidence of D4Ag's impact and key impact gaps— the USAID- and BMGF-funded study, "Agriculture in the Digital Age"—supported these findings, stating that there is "a lack of quality, empirical data to draw conclusions about actual use and outcomes [of digitally enabled agricultural services]. Most of the evidence is clustered to just a few countries, and analysis is limited to looking at the impacts on individuals." According to the study, just seven countries represent more than 75% of the published evidence: India, Kenya, Ghana, Uganda, Indonesia, Nigeria and Tanzania.

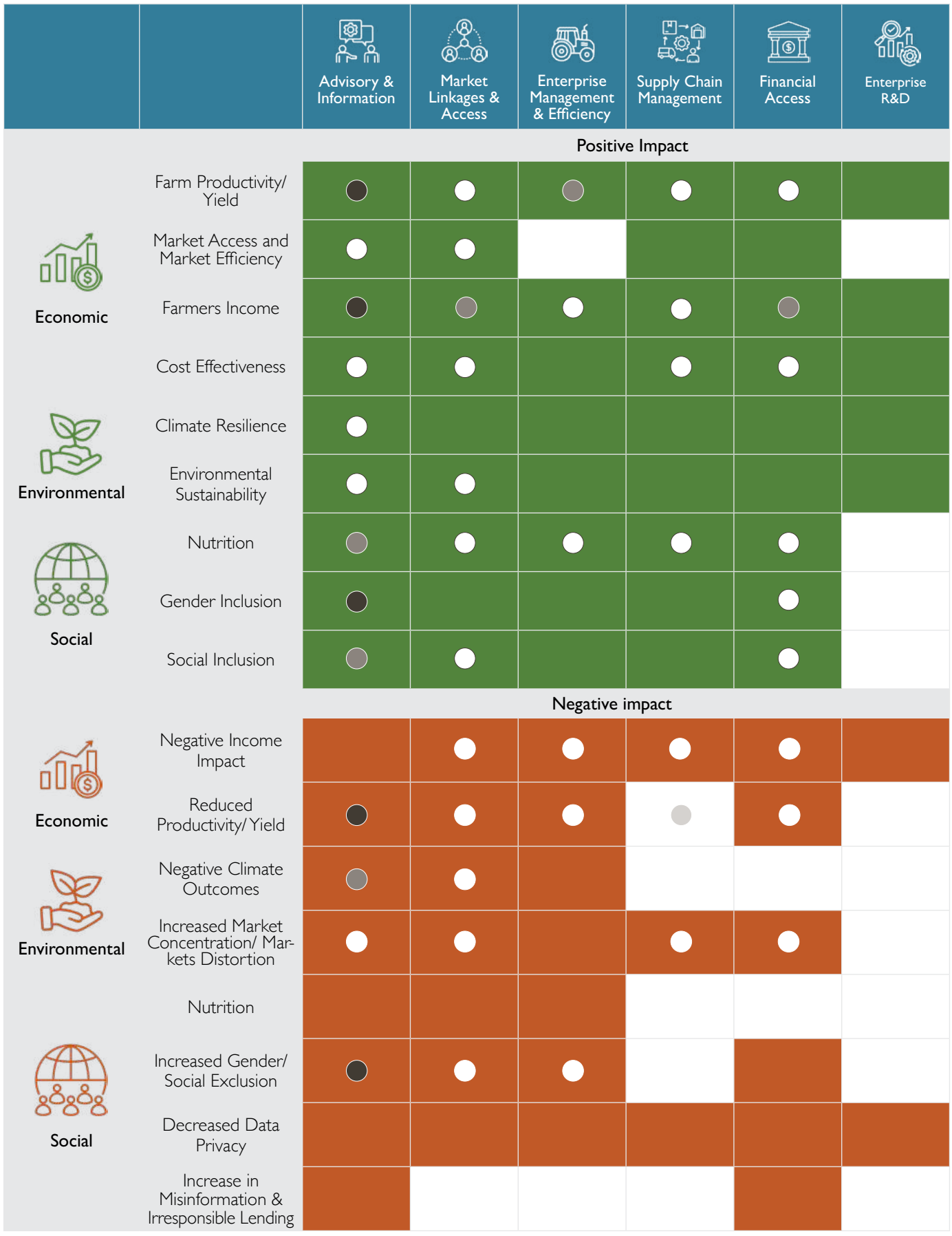


Figure 45. Observed Vs. Theoretical Impact of D4Ag. Source: Agriculture in the Digital Age

Our interviewees voiced recurring concerns regarding the assessment of the impact of D4Ag, underscoring the necessity for a clearly defined and consistent approach to measurement. For donors, the lack of standardized measurement hinders outcome-oriented capital deployment; for startups, it complicates conveying value to farmers and funders, limiting their ability to attract investment and scale. For investors, inconsistent assessment disrupts conveying outcomes to Limited Partners, many of which are Development Finance Institutions in LMICs, and impedes the shift to an authentic "impact investment" model, potentially eroding credibility and trust among various stakeholders. These concerns encapsulate three main aspects.

Firstly, there is ambiguity around ***what*** constitutes "impact." The term is often used interchangeably, especially by D4Ag innovators, to reflect solely the number of farmers they are engaging, instead of actual outcomes such as increased yield, improved income, enhanced resilience, or social inclusion, among others. This lack of consensus on defining "impact" makes it difficult to compare and evaluate the effectiveness of different D4Ag initiatives, and currently the default remains to measure "access" over "impact," with success often quantified based on the number of farmers who have access to or use D4Ag too. This approach, though straightforward, falls short in reflecting the actual effect of these tools on improving productivity, income, or other desired outcomes.

> *"I think we ask the wrong question. After this person has engaged with all of us for three years, why is their life the same? This is the impact we expect to see. And not that we have a 1,000 people signed on a platform. That can't be the measure of success. And I think that is driven by multiple factors starting with what do donors consider success, what do NGOs consider success, and who's the person who can hold each one of us accountable."*
>
> NGO, sub-Saharan Africa

Second, there is little consistency in ***how*** impact is measured. Different stakeholders may employ different metrics and methodologies, leading to inconsistent and sometimes contradictory findings, creating confusion and making it challenging to compare the impact of various interventions. The lack of common and standardized taxonomies, metrics, and methodologies for "impact" in D4Ag currently hampers the ability to effectively compare and analyze the effectiveness of different D4Ag interventions across diverse projects or regions.

However, a potential opportunity lies in leveraging existing providers and stewards of investor and commercial standards such as B Corp, IRIS+, ISEAL, and 60 Decibels. These entities already possess comprehensive metrics and rigorous methodologies that are widely recognized and used in other sectors. Adapting these to develop appropriate standards for D4Ag tools could establish much-needed consistency and comparability within the field.

In 2023, the Global Impact Investing Network (GIIN) Impact Lab has introduced a first of its kind Impact Performance Benchmark for measuring impact in agriculture, which holds the promise to revolutionize the field by providing clear and standardized guidelines that can be uniformly applied across the sector. The benchmark has been built in collaboration with 16 impact investment funds, and now contains data about 479 investment into the agricultural sector.

The tool now allows investors to measure impact performance of their investees across seven key KPIs:

Farmers accessing responsible agriculture products, services and trainings

738

Farmers are associated with investment (investment-weighted) in a given year, on average, with 250 being women

Agricultural MSMEs financed responsibly

19

MSMEs financed responsibly through investee activity on average, each year

Change in farmer income

9.2%

Change in farmer income at the median

Sustainably managed land

1,224 acres

Of land (investment-weighted) are associated with investments in a given year, on average

Greenhouse gas emissions mitigated

Insufficient data available for inclusion in the benchmark, as of 2023

Decent jobs supported at or above a living wage

13

Decent jobs are created (investment-weighted) in a given year, on average

Investee revenue growth

48.5%

Growth experienced by investees

Figure 46. IRIS+ Impact Standards for Agriculture (numbers as of July 2023)

Source: Feed the Future Flickr. Photo credit: Petra Dilthey

Lastly, the question of ***who*** should measure impact is crucial. Some stakeholders may have biases or vested interests that could influence the measurement and reporting of impact. Therefore, it is critical to establish independent, neutral entities for impact assessment to ensure objectivity and credibility. Measuring the impact of D4Ag is fraught with commercial, social, and technical constraints. For innovators and investors, impact measurement can be expensive and time-consuming, falling outside their core capabilities and distracting from the day-to-day obligations to manage and grow a fledgling business. Yet, there is an opportunity for donors to scale up, professionalize, and subsidize impact assessment services for startups in LMICs. In addition, public facing data platforms, such as AgBase, can showcase solution-level and market-level impact metrics on their platforms. Conversely, there is a concern that in-depth impact measurement could reveal inefficiencies, threatening fund credibility and investment returns. Despite this, impact often serves as a "compliance" metric rather than a "value" driver, even among impact investors, with commercial outcomes taking precedence over increasing scale of impact.

> *"Of course people talk about impact, and they know roughly what it would mean to get to impact, but the ambition is often not necessarily to really be very rigorous with the impact measurement because it's perceived as expensive and cumbersome. And again, people don't know what the methodologies would be."*
>
> GESI Expert, Global

The challenge of defining and measuring impact in a clear and credible way has led some organizations to seek external expertise. For instance, one of our interviewees mentioned that they are collaborating with an independent impact measurement consultant, helping them to facilitate objective and robust impact reporting and lend additional credibility to their initiatives.

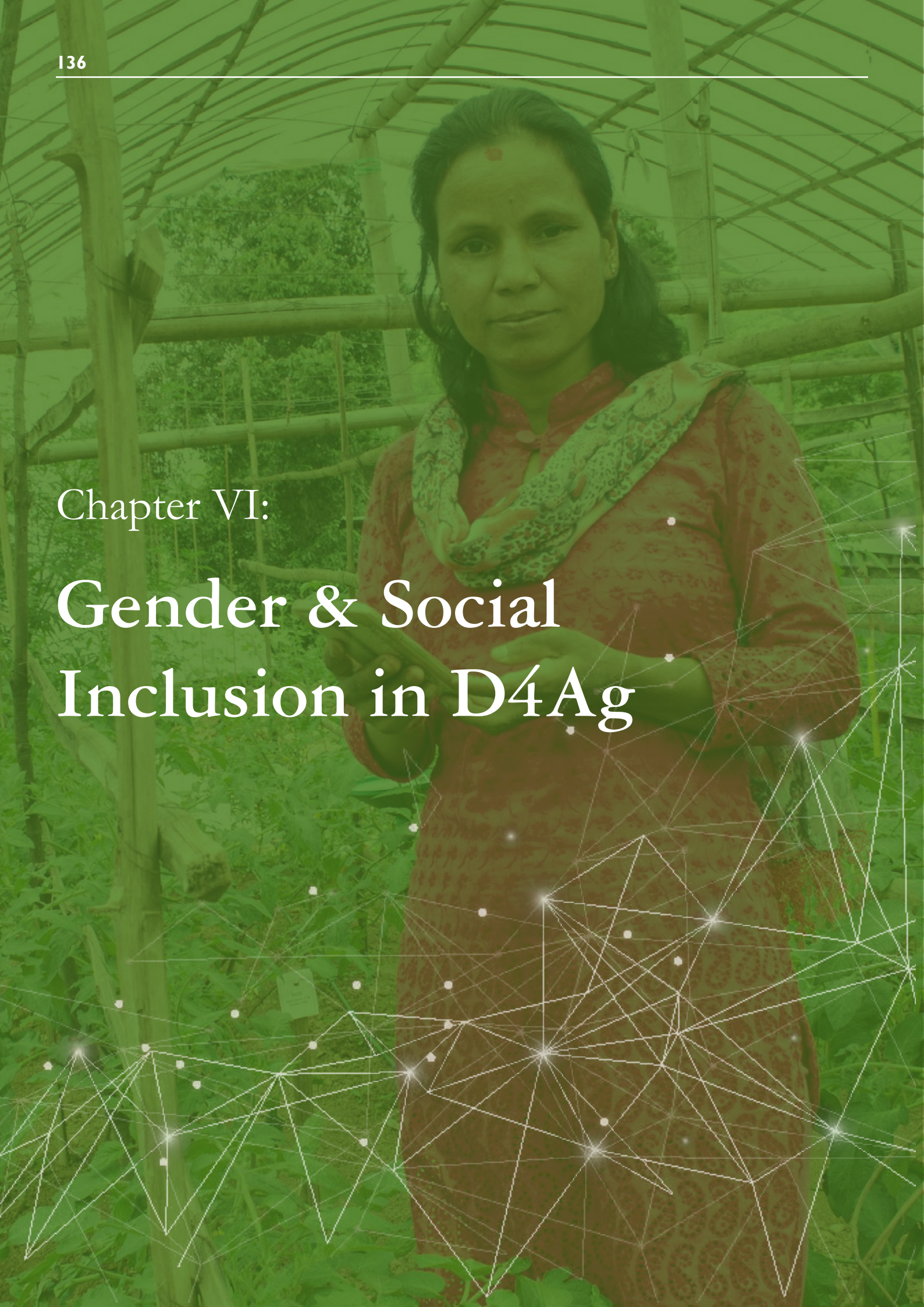
MEASURING IMPACT OF D4AG ON VULNERABLE POPULATION GROUPS

Social constraints to quality impact measurement particularly involve the additional cost and complexity when targeting potentially disadvantaged sub-populations, such as indigenous communities, LGBTQIA+ individuals, and people with disabilities.

Privacy Concerns and "Outing" Dangers: In the case of LGBTQIA+ individuals, for instance, collecting information about sexual orientation or gender identity can risk exposure or "outing" in communities where such identities may be stigmatized or criminalized. This necessitates stringent privacy protections and ethical considerations, which can require special protocols and consent processes, adding to the complexity and cost of research.

Navigating Cultural Sensitivities and Norms in Indigenous Cultures: Engaging with indigenous communities often means understanding and respecting unique cultural norms, values, and traditions; and requires investing in community liaisons or cultural experts who can guide the approach, ensuring that research or interventions are conducted in a culturally sensitive manner. Such engagements might also require more time and resources for building trust and collaboration, making it both a complex and costly endeavor.

Specialized Approaches for People with Disabilities: The term "disability" encompasses an incredibly diverse and varied range of experiences, needs, and challenges, adding complexity to the development of appropriate tools and methodologies. In many communities and cultures, people living with disabilities (PLWD) are often "hidden" due to societal stigmatization, making it difficult for researchers and practitioners to fully understand and cater to their needs. When engaging with PLWD, it is crucial to adopt specialized, accessible, and inclusive tools and methodologies. Examples include accessible survey instruments, sign language interpreters, and transportation accommodations. However, given the vast range of disabilities and the nuanced challenges within each, creating a universally accessible and inclusive environment is intricate. It often demands additional resources, specialized knowledge, and a deep understanding of the context. To truly ensure inclusivity and address the multifaceted challenges, collaboration with community-based organizations that specifically focus on disability rights is essential. These organizations possess the grassroots knowledge and networks to ensure that research and interventions are genuinely inclusive, and that the voices of PLWD are centered in the conversation.and transportation accommodations. However, given the vast range of disabilities and the nuanced challenges within each, creating a universally accessible and inclusive environment is intricate. It often demands additional resources, specialized knowledge, and a deep understanding of the context. To truly ensure inclusivity and address the multifaceted challenges, collaboration with community-based organizations that specifically focus on disability rights is essential. These organizations possess the grassroots knowledge and networks to ensure that research and interventions are genuinely inclusive, and that the voices of PLWD are centered in the conversation.



Chapter VI:

Gender & Social Inclusion in D4Ag

When discussing "inclusion" within the context of digital technology and D4Ag, a unique paradox emerges. While on one side, digital platforms have an opportunity to catalyze engagement, give rise to new communities, and empower marginalized voices, on the other side, they can mirror existing societal dynamics and power structures, furthering exclusion and inequality among already underprivileged social groups. Building inclusive and sustainable digital agriculture ecosystems involves concerted efforts across all facets of the ecosystem, spanning its foundations, solutions deployed, the means of reach and adoption, to impact assessment. Discussions about "gender & social inclusion" for D4Ag must recognize the diverse and often intersecting social political and cultural identities including—but not limited to—sex, gender, age, ability, ethnicity, sexual orientation and gender expression, Indigeneity, land status, and colonial history can expose sub-populations to further marginalization. The scale, societal and economic positioning, and challenges facing these respective sub-populations differ greatly both within and across regions, and thus, designing "inclusive" D4Ag solutions is invariably local, personal, and granular with very few shortcuts.

Source: Feed the Future Flickr. Photo Credit: Robic Upadhyaya/KISAN II, Winrock International

The landscape of evidence, research, programming, and solution development within the D4Ag sector is marked by significant variability across different sub-populations and sociodemographic factors. While a considerable portion of research, solutions, and impact evidence centers around low-income populations, as well as women and youth, other underprivileged goups such as people with disabilities, LGBTQ+, indigenous, and ethnic minorities often remain overlooked. This disparity highlights an unequal focus, potentially sidelining essential insights and needs that could contribute to more inclusive and effective solutions within the sector.Additionally, there seems to be a gap in the translation from existing research into targeted solution development. Our interviewees commonly noticed a

Attention to and evident impact from D4Ag varies across socio-demographic factors

Greater investment on "gender equality" than "social inclusion" to date

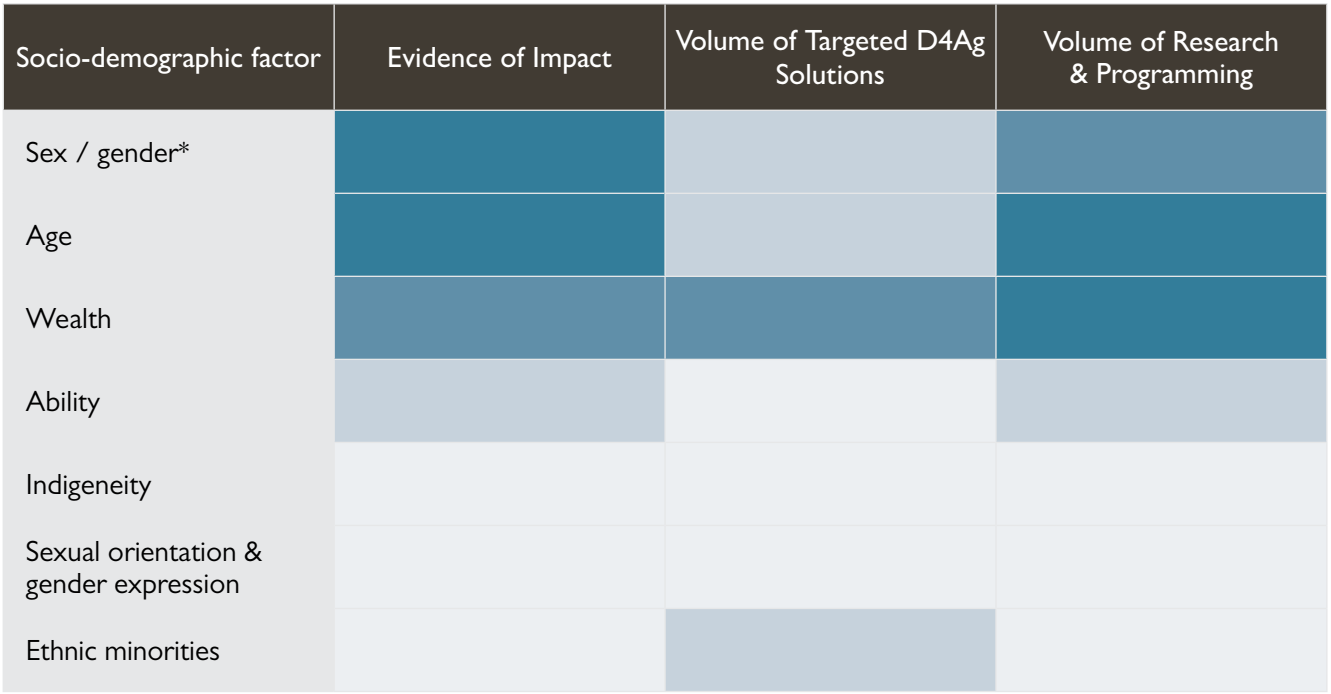


Figure 47. Depth of D4Ag Impact Evidence on Gender & Social Inclusion

disconnect between the findings of research and their practical application in designing tailored solutions, hindering the ability to address specific challenges and opportunities, and thereby limiting the potential impact on diverse and underserved communities. Emphasizing a more coherent integration between research and solution development could foster a more comprehensive approach, extending the benefits of D4Ag innovations to a broader spectrum of the population. However, challenges such as the lack of diversity at the foundational level can mirror biases and inequalities at a systemic level. In this case, solutions are inadvertently designed in ways that align with societal norms and expectations, which can perpetuate stereotypes and lead to the exclusion of specific cohorts. Second, there exists a knowledge gap, as many stakeholders lack GESI-specific training, which affects the understanding of the importance of disaggregated data and its application to create inclusive systems. Lastly, the prevailing funding model and cycle often do not provide ample time for in-depth co-design processes, further

reinforcing the "invisibility" of women in various agricultural roles and overlooks certain subpopulations.

Despite the wide-ranging differences in access, uptake, effective use, and impact of D4Ag across these sub-populations, several encouraging common impact stories are observed, with women and other marginalized groups at the center of these narratives. Verified studies have confirmed the positive effect of digital tools on female farmers' incomes and productivity. In our interviews, we have also seen actual examples of positive impact of D4Ag on job creation, providing access to services or inputs that were earlier unavailable, as well as improving access to finance for women.

wtt World-Transforming Technologies

Foundation, Brazil: "We have a cell phone application to form female investment and savings groups, also monitoring and evaluating those. This had a great impact on those rural communities because women are then organized and [they] got the ownership of their money. We have many different interesting stories about men trying to stop women from doing that, but they are thriving and being able to get empowered by the management of their own financial resources".

ACCESS TO FINANCE

Babban Gona better your life

D4Ag Innovator, Nigeria: "We have trained and supported 230,000 women, using our female-focused programs. And also, to mention of 600,000 the jobs that we've created, over 70% of the jobs we've created have gone to youth and about 50% of those jobs have been for women."

*The program is focused on training rural women to become financially independent through micro-entrepreneurship and a combination of formal training and credit packages. The training helps to provide business and financial literacy skills needed to start and sustainably run and manage a business.

JOB CREATION

TROTRO Tractor Limited

D4Ag Innovator, Nigeria: "It's a cultural practice that is happening. In the northern part of Ghana and Nigeria, when a tractor gets to the community, it will serve all the men before it comes to the women. But we look at first-come-first-served; who makes the request first, gets the service, overcoming this barrier."

ACCESS TO SERVICES/INPUTS

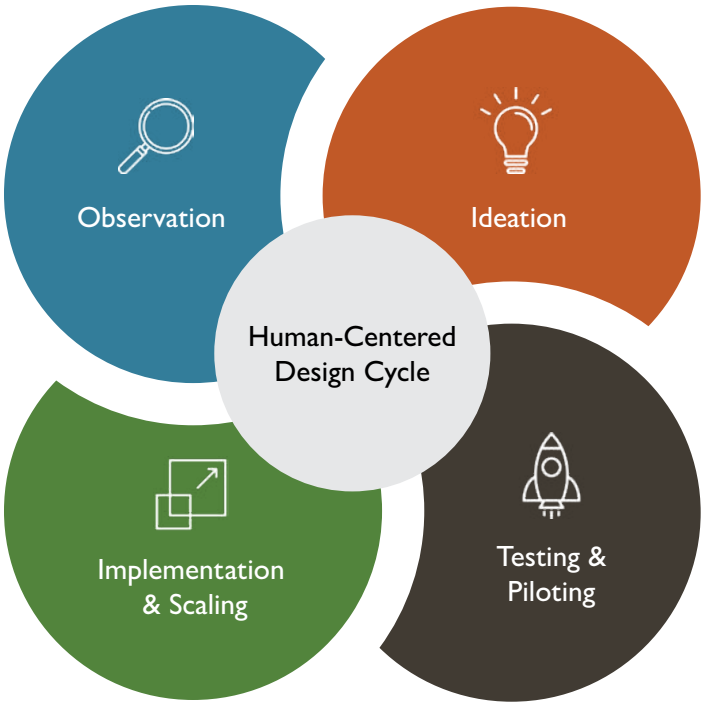
Source: Beanstalk Key Informant Interviews, 2023

Figure 48. Examples of D4Ag Impact on Gender Inclusion

DESIGNING INCLUSIVE D4AG SOLUTIONS

There has been a great amount of dedicated research to the best practices for designing inclusive D4Ag tools. One of the latest publications by CGIAR Gender Platform—"Designing Gender-Inclusive Digital Solutions for Agricultural Development" (2022) introduces the concepts of human-centered, participatory design process that can enhance understanding of diverse user needs and support the creation of more gender-inclusive and widely scalable digital tools, fostering a sense of empowerment and ownership among users. The toolkit and guide provide practical actual tools for the different steps of such a design process. However, translating these narratives into practice has often proven to be challenging for several reasons. The development of truly inclusive D4Ag tools requires a comprehensive understanding of the varied roles, needs, and challenges of different sub-populations, and the first step in this process is to acknowledge that individuals' roles are not static but vary across geographical locations, times of the day, seasons, and life stages. By accommodating this variability in the design of D4Ag solutions, innovators can ensure that these tools are more accurately tailored to meet the needs of diverse sub-populations.

Besides women, there is a need to understand an intersectionality of identities within different social groups—like people living with disabilities, older populations, and others—to effectively meet the needs of target users. For instance, the company **CoAmana** discovered through data disaggregation and gender analysis that older women were three or four times more expensive to service on their platform due to a higher-than-average number of customer calls.



1. OBSERVATION

Develop a good understanding of the problem, its root causes, and the users' context, constraints, wishes and needs.

2. IDEATION

Come up with ideas that could solve the problem.
a. GENERATING IDEAS
b. PROTOTYPING

3. TESTING & PILOTING

The ideas are tested by users hands-on.
a. PROTOTYPE TESTING
b. PILOTING

4. IMPLEMENTATION & SCALING

After improvements based on the pilot phase are implemented, the solutionis ready for further scaling, bringing it to more users.

Figure 49. Steps in The Human-Centered Design Cycle. Source: CGIAR[43]

43 Designing Gender-Inclusive Digital Solutions for Agricultural Development, CGIAR, 2022

This insight led them to expand their call center services to cater specifically to this sub-population.

For the advancement of gender equality and social inclusion in D4Ag to be realized, a shift efforts is essential: Although the role of donors remains vital in initiating and supporting these objectives, it should not be relied upon as the sole mechanism for change. However, even the development sector's initiatives often struggle with various problems. For example, our interviewees commonly mentioned the need for adoption of longer and more adaptive donors' project timelines, as well as the supporting funding for such development sector's initiatives. Even though there is little visibility into the reasons for "failed" initiatives, it is well known within the development and tech sector that a significant number of projects do not reach their full potential or fail entirely due to ill-fit or mismatched timelines. The long-term approach is crucial in the realm of agriculture due to the complex nature of understanding, engaging, and catering to the needs of various sub-populations, which demand extensive research, co-creation of solutions, behavior change facilitation, and trust-building—elements often compromised in short-term projects. Additionally, longer-term projects provide room for iterative design and the development of sustainable business models over the course of the natural agricultural life cycle, thereby fostering enduring impact and real transformation in gender & social inclusion. While clearly the main challenges to implementing this approach are related to time and budget constraints among the projects' funders, it is important to test these

Source: Feed the Future Flickr. Photo credit: Arpan Basu Chowdhury

to understand their tradeoff with the observed incremental impact. The pressure to deliver quick results can lead to shortcuts or a focus on short-term gains, at the expense of long-term sustainability and impact.

Incentives play a crucial role in fostering sustained inclusivity in D4Ag, as they have the potential to engage and motivate different stakeholders, from both the demand and supply side of the innovation. From a demand perspective, we have seen cases of financial incentives, such as discounts or subsidized rates for services, which can make the technology more accessible to users, particularly marginalized groups. For instance, **HelloTractor** encourages female participation by offering lower financing rates to women. Such initiatives not only promote inclusivity but also create economic opportunities for marginalized groups, breaking down barriers to their participation. A combination of both demand and supply incentives, tailored to the specific context and target group, will likely have a greater success in promoting long-term inclusion in D4Ag.

To ensure comprehensive inclusivity in the D4Ag sector, a systemic approach is paramount, emphasizing the interconnectedness of components of the D4Ag ecosystem and recognizing that effective and inclusive D4Ag solutions require understanding and addressing systemic biases and barriers all the way from the ecosystem's foundations. A foundational element in this process is the GESI training of all stakeholders throughout the D4Ag ecosystem, equipping them with the requisite skills and mindset to follow GESI-sensitive approaches. This would empower them to craft and implement solutions that not only recognize but also cater to the diverse needs and challenges of various cohorts. Furthermore, robust GESI policies at both government and institutional levels are critical for further advancement of inclusive D4Ag ecosystems. These policies should serve as a guiding framework, ensuring that inclusivity is not merely an afterthought but is ingrained into the fabric of every initiative. Only with a systems-focused approach can we hope to create a D4Ag ecosystem that is genuinely inclusive and equitable for all.

ENSURING INCLUSIVE DELIVERY MODELS OF D4AG INNOVATIONS

To ensure that D4Ag innovations are inclusive, it is critical to consider appropriate delivery models that cater to the specific needs of the diverse user groups. Digitally, social media platforms can provide a powerful means of engagement, given their wide reach and ease of use. This can facilitate the dissemination of information and provide an interactive platform where users can ask questions and provide feedback.

Physically, using the already-mentioned intermediary-led approaches can help bridge the gap between the technology and the users. For example, the **RehApp** application developed by **Enablement**, which serves to educate caregivers, community members, and health professionals working with people with disabilities, informs them about various inclusion challenges and offers ways to provide support, including modules on digital agricultural tools. This direct, on-the-ground approach helps to ensure that D4Ag innovations are relevant and beneficial to those who need them most. The application is offered to field workers in LMICs free of charge.

For culturally and linguistically diverse populations, or those with limited literacy, alternative communication methods have been successfully used with clear evidence of impact. IVR and video are particularly effective, offering a more intuitive, accessible way for users to engage with the technology. These can also be beneficial for people with limited vision or

Source: Feed the Future Flickr. Photo credit: Mohammad Al-Nashili

hearing, ensuring that D4Ag innovations are accessible to all.

PRESSING CHALLENGES TO GENDER & SOCIAL INCLUSION

Gender Data and Data Architecture:
Despite the occasional self-selecting survey, we still have relatively little visibility regarding the proportion of women, let alone other sub-populations, that are engaged and active on D4Ag solutions being deployed today.

Even though, according to our interviews with D4Ag innovators, more than 75% of them do collect gender-disaggregated data, at least at registration, almost none of this data is being used. This means that data segregation often ends at the "registration" stage, and there is a significant drop in information segregation beyond that point, leaving us with little understanding of the real usage patterns. This discrepancy can be attributed to various reasons such as data architecture foundations and maintenance challenges, resourcing, and knowledge among others. However, it is altogether a missed opportunity to improve the value delivered by individual D4Ag solutions and to generate knowledge regarding further limitations and enablers of success in the engagement of women and other sub-populations across their business cycles.

Common Lack of GESI Knowledge:
There is a clear tendency by innovators and donors to group all "marginalized" sub-populations together rather than explore their

unique needs and challenges, leading to less clear value propositions and engagement pathways. There is a need for D4Ag tools that focus on solving specific inclusion challenges one at a time, even if that means a slower growth or smaller scale.

Access and Representation Across the Ecosystem:

Lastly, there is a general lack of "representation" of different sub-populations across the D4Ag ecosystem. This lack of representation is reflected in the roles of innovators, investors, agribusiness leaders, extension agents, and more. Social and cultural stigmas, prejudices, and biases continue to play a massive detrimental role in this regard, affecting opportunities for D4Ag entrepreneurs and the specific solutions designed for different groups. Despite this, it is encouraging to see growth in the number of D4Ag startups founded or led by women, but there is still a long way to go.

Women are significantly underrepresented in the digital agriculture sector. In LMICs, women constitute 43% of the agricultural labor force in LMICs but, for example, only 22% of bank account holders in rural areas are women, and women are 33% less likely than men to own a mobile money account, which leads to unequal access to financial resources.[44] [45] Women are often also less supported in training and capacity building, compared to men: from GSMA-supported digitalized agriculture value chain projects, only 17% of farmers are women. This further increases the existing knowledge and digital literacy gap between men and women.

Source: Feed the Future Flickr. Photo credit: Mir Raihanul Islam, IFPRI

44 Recognizing the Agricultural Efforts of Women, CGIAR, 2021
45 Global Findex Database 2021.

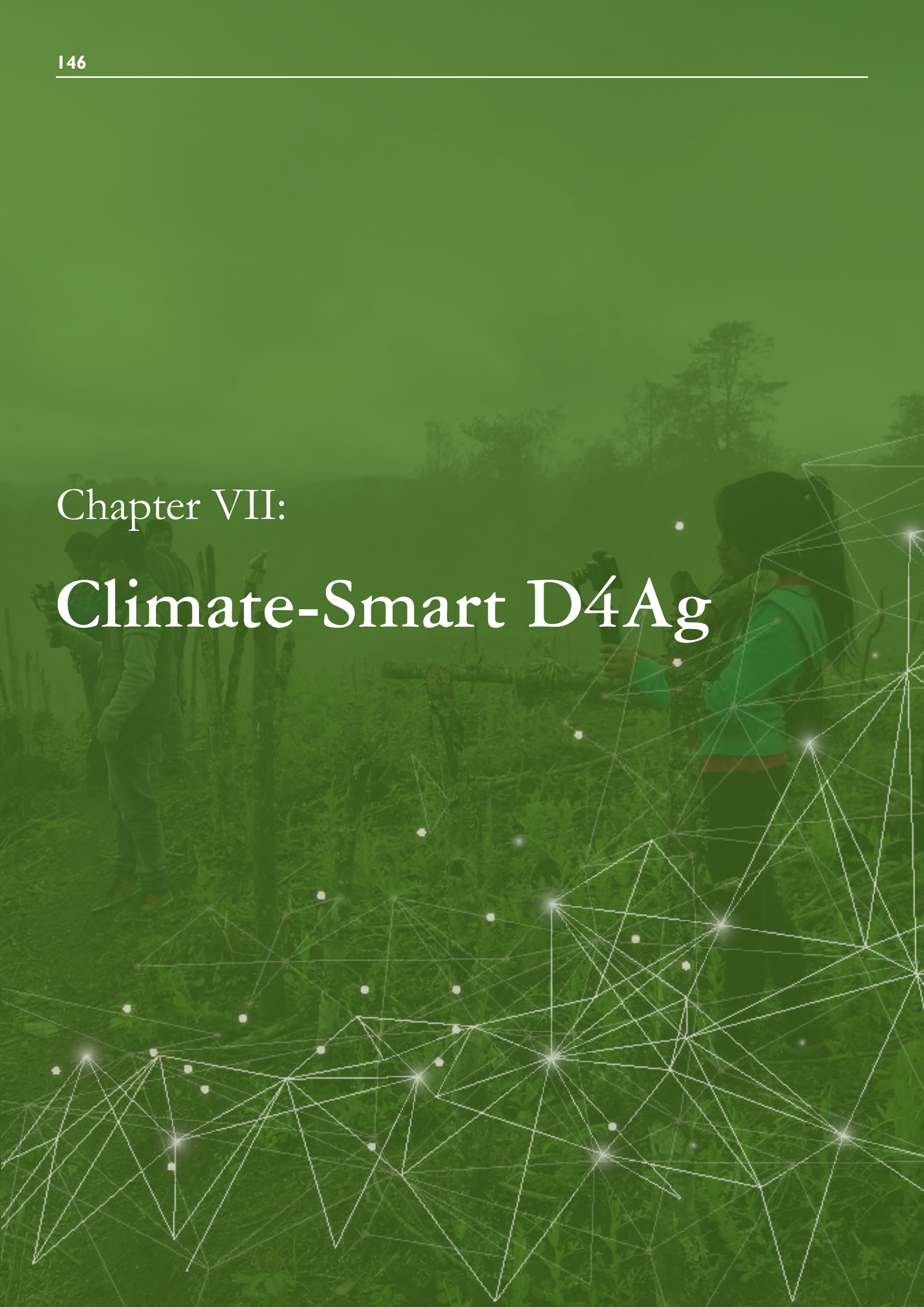
Moreover, according to the GSMA Gender Gap 2023 report, women in LMICs are 19% less likely to use mobile internet than men and are 17% less likely to own a smartphone. This digital divide is especially prominent in South Asia and sub-Saharan Africa, with gender gaps in mobile internet use of 41% and 36% accordingly.

While participation rates in agriculture and farming may be higher at the country level, it does not always translate to better outcomes. For example, for Ivory Coast's cocoa industry, women make up for 68% of the farming workforce, but only earn 21% of the income generated.[46] In India, 80% of women work in agriculture, but less than 15% own land.[47] In Rwanda, although women account for 76% of agriculture employment , they are less likely to use any new technologies; therefore, as D4Ag solutions grow, women continue to be disadvantaged. According to the FAO, globally, women earn 82 cents for every dollar earned by men in agricultural wage employment and are less likely to be involved in more profitable activities and the production of higher value crops.[48]

The underrepresentation of women in the digital agriculture space is also evident in our interaction with D4Ag innovators. From the 54 innovators we interviewed and 49 surveyed, respectively 18% and 17% are women. As an innovator shared during the interview, "it's just [the cultural norm] that … the business belongs to men." The proportion of female clients reached by these D4Ag tools vary widely with an average of 26%, while the proportion of female employees from these companies is on average 41%. Moreover, women are less likely to attract investor funding to their startups than their male peers: According to CSAF, women receive only 7% of agricultural investment.[49] This is particularly concerning, given the evidence that female-led enterprises have more stable revenues, are more profitable (on average they yield $17,850 more profits than loans to non-women-led enterprises), and are very fast-growing.[50]

There is also a pressing need for a common taxonomy and set of indicators for impact measurement, including gender & social inclusion impact. One of the most advanced tools used to measure the empowerment, agency, and inclusion of women in the agricultural sector is the Women's Empowerment in Agriculture Index (WEIA), launched in 2012 by USAID, IFPRI and Oxford Poverty and Human Development Initiative. The baseline survey conducted by USAID Feed the Future initiative in 2014 concluded that "on average, women are twice as disempowered as men; at the extremes, women are about three times as disempowered as men." [51]

46 Economic Empowerment of African Women through Equitable Participation in Agricultural Value Chains. AfDB, 2015.
47 India Development Review, 2022
48 The Status of Women in Agrifood Systems. FAO, 2023
49 Closing the gender gap in agricultural investments. CSAF, Root Capital & Value for Women, 2023.
50 Inclusion Pays: The Returns on Investing in Women in Agriculture, Root Capital, 2022.
51 Measuring Progress Toward Empowerment. Women's Empowerment in Agriculture Index: Baseline Report. IFPRI, 2014

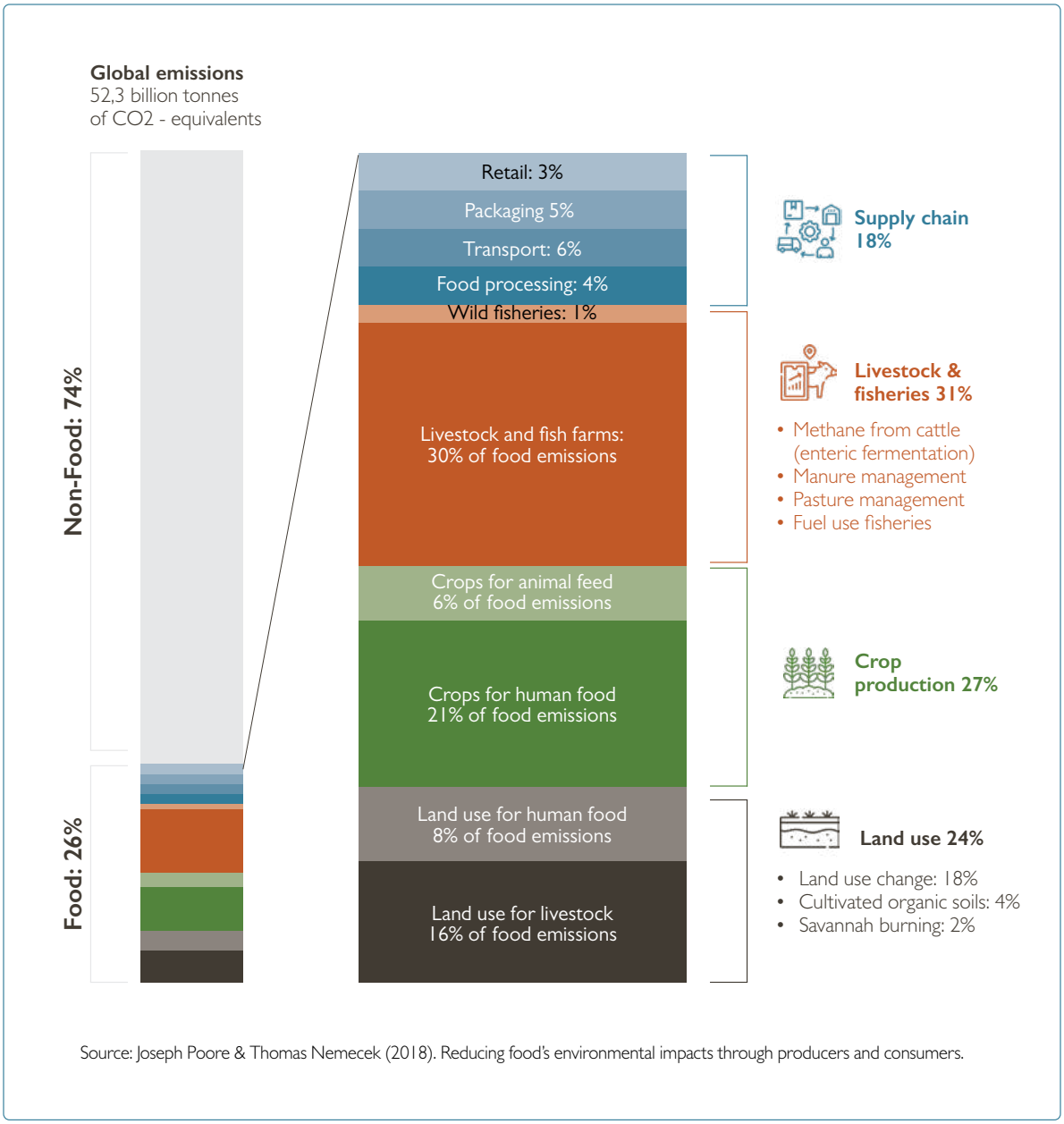


Chapter VII:

Climate-Smart D4Ag

Climate-smart digital agriculture encompasses a range of innovative solutions that have the potential to revolutionize agricultural practices. These solutions—when integrated with policy frameworks, physical infrastructure, and other components of climate-smart agriculture—hold immense potential for enhancing environmental sustainability within agricultural value chains, although the empirical evidence to corroborate this is still relatively limited.

The agriculture industry is widely understood to be a major driver of climate change, however exact estimates of total emissions from the sector vary. IPCC states that, on average, the Agriculture, Forestry and Other Land Use (AFOLU) sector accounted for 13%–21% of global total anthropogenic GHG emissions in the period 2010–2019.[52] The sector is estimated to emit net +5.9 ± 4.1 GtCO2 yr–1 between 2010 and 2019 with an unclear trend.[53]



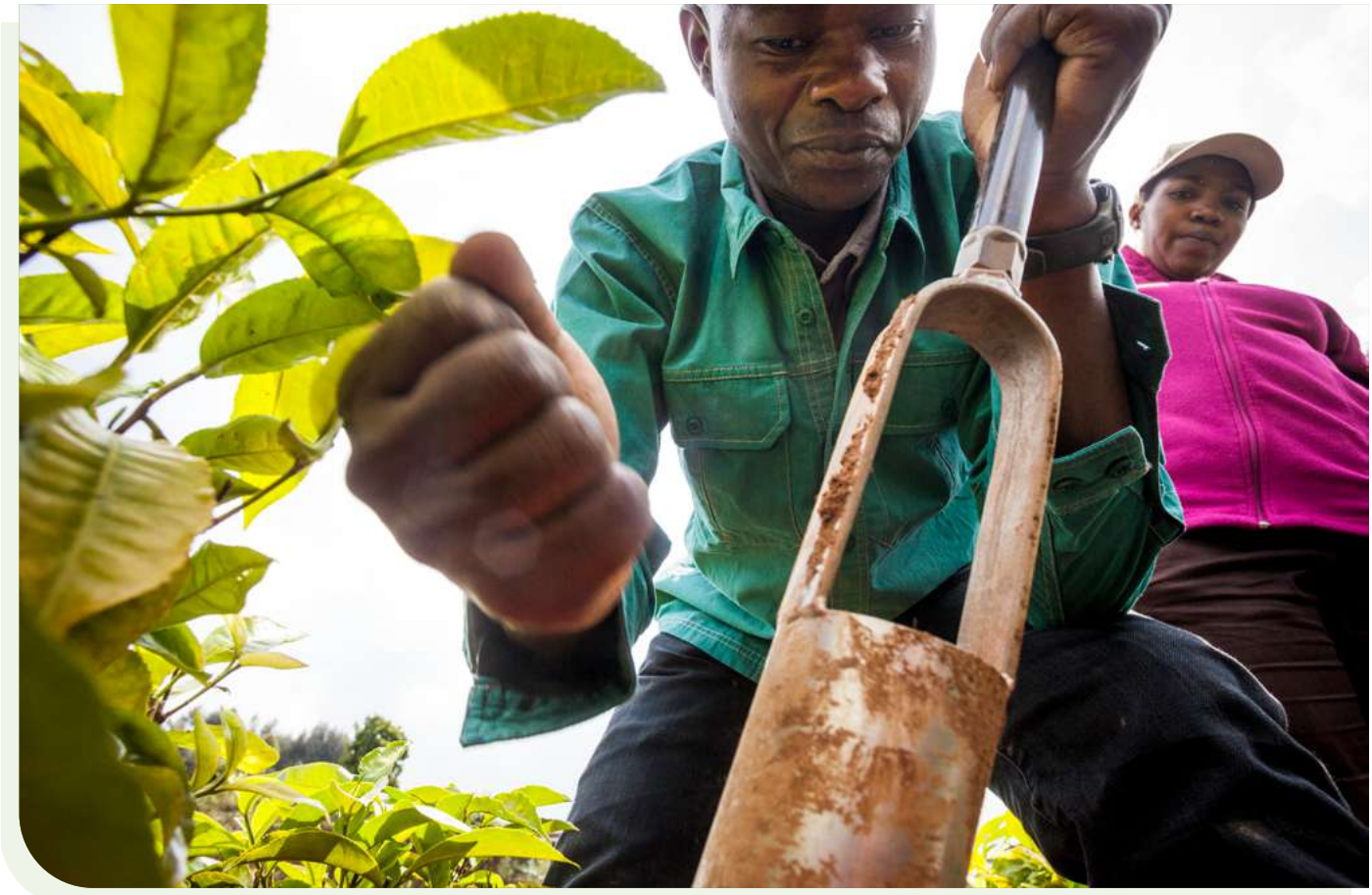
Source: Joseph Poore & Thomas Nemecek (2018). Reducing food's environmental impacts through producers and consumers.

Figure 50. Global GHG Emissions from Food Production, 2020

[52] IPCC AR6 IPCC_AR6_WGIII_Chapter07.pdf
[53] IPCC AR6 IPCC_AR6_WGIII_Chapter07.pdf

The World Resource Institute estimates that the Agriculture, Forestry, and Land Use sector directly accounts for 18.4% of global emissions (CO2 equivalent). However, when considering the food system as a whole, which includes aspects like refrigeration, food processing, packaging, and transport, it accounts for around one-quarter of greenhouse gas emissions.[54] This is particularly pronounced in the production of two specific greenhouse gases: nitrous oxide (N2O) and methane (CH4). Agricultural methane (CH4) and nitrous oxide (N2O) emissions are estimated to average 4.2 ± 1.3 and 1.8 ± 1.1 GtCO2-eq yr–1 respectively between 2010 and 2019. CH4 emissions continue to increase, the main source of which is enteric fermentation from ruminant animals, and N2O emissions are increasing, dominated by agriculture, notably from manure application, nitrogen deposition, and nitrogen fertilizer use.[55]

On the other side, the agricultural sector and its workforce are especially susceptible to the impacts of climate change. This vulnerability is accentuated in low- and middle-income countries due to the substantial climate financing gaps, underdeveloped safety nets, and lack of infrastructure and technological buffers. Digital tools, however, have a crucial role in improving the accessibility, effectiveness, and cost efficiency of deploying climate-smart agriculture practices at scale.



Source: Feed the Future Flickr. Photo credit: Benjamin Drummond

[54] Our World in Data: Emissions by sector, 2020
[55] IPCC AR6

Source: Feed the Future Flickr. Photo credit: DINESH G K

Direct Impacts	Production & System-Level Impacts	Socioeconomic Impacts
• Changes in temperature and precipitation patterns • Increased frequency and intensity of extreme weather events • Water scarcity • Soil degradation • Shifts in crop suitability • Impact on pollinators and biodiversity • Increased prevalence of pests and diseases	• Reduced crop yields and increased crop failure • Changes in livestock productivity and management • Alterations in farming practices and crop types • Disruptions to food production and distribution	• Decreased food security and nutrition • Income loss and increased poverty • Forced migration and displacement • Strains on local and regional economies

Figure 51. Impacts of Climate Change on Smallholder Farming Systems

D4Ag can play a role in advancing the core pillars of climate-smart agriculture: mitigation, adaptation, and resilience. Mitigation involves digital tools that help reduce the environmental impact of farming and agricultural value chain practices. Adaptation & resilience involves digital tools that support farmers and value chain actors in adjusting their farming practices in response to the changing climate and improving their ability to recover from climate-driven adversity.

Use case	Solutions	Mitigation	Adaptation & Resilience
Advisory & information	• Climate advisory services • Agronomic advisory services • Macro intelligence	• Reduction of inputs (e.g. water, fertilizer, pesticides) and greenhouse gas emissions • Carbon tracking and management, enabling opportunity identification for emissions reduction and potential carbon offsets • Identification of market trends and opportunities for implementation of sustainable production and business practices	• Informed decision-making for planting & harvest schedules • Knowledge-sharing for collective adaptation to new challenges and opportunities • Identification and response to emerging threats • Optimized adaptation of production practices to changing climate condition
Market linkages & access	• Market information systems & advisory services • Input digital marketplaces • Output digital marketplaces • Offset digital marketplaces • Digital leasing and service provision	• Informed decision-making to reduce risk of overproduction and food waste • Incentivize and monetize sustainable production practices (e.g. carbon sequestration, biodiversity conservation)	• Access to inputs and equipment required to adapt to changing climate conditions (e.g. drought-resistant seeds, irrigation systems, equipment leasing) • Financing and scaling of adaptation measures (e.g. water harvesting, soil conservation)
Enterprise Management & efficiency	• Farm management systems • Enterprise and resource management • Compliance and safety	• Optimization of production practices for waste and emission reduction • Identification of cost-saving opportunities and areas, allowing investment in sustainable production practices • Food waste reduction through appropriate crop & livestock production and handling	• Access to agrometeorological information enables adjustment of production practices • Workforce optimization, ensuring necessary labor force to adapt to changing climate conditions
Supply chain management	• Traceability and transparency • Logistics and inventory management • Quality control, assurance & certification • Impact MRV tools	• Quick identification of contaminated/ spoiled products to reduce need for large-scale waste • Route optimization and travel distance reduction • Reduction of emissions related to overproduction and overstocking	• Quick response and adjustment of production and supply chain strategies • Risk mitigation through quick rerouting and identification of alternative transportation options • Supply chain disruption management
Financial access	• Digital payments and banking • Savings and credit • Insurance & risk management	• Enabling smallholders to invest in sustainable and climate-smart farming practices (e.g. agroforestry, conservation agriculture) • Financial risk management (e.g. crop failure due to extreme weather events) • Investment and support of sustainable and climate-resilient businesses	• Investment in adaptive measures (e.g. water harvesting, improved irrigation systems) • Access to flexible and accessible funding sources to adapt to changing market and weather conditions
Enterprise R&D	• Market research & analytics • Open innovation platforms • Digital prototyping & automation • Discovery platforms	• Development of new products and services that reduce emissions from agricultural activities (e.g. low-emission fertilizers, precision agriculture) • Encourage adoption of climate-smart technologies and practices	• Development of new products and services that promote adaptation to changing climatic conditions and extreme weather events (e.g. drought-resistant seeds, precision irrigation) • Timely and data-based decision making

Table 13. Relationship between D4Ag X Climate Outcomes

Despite the many promising benefits of digital technologies to farmers and the environment, the reality is far more complex and can involve tradeoffs. These technologies can increase the use-efficiency of natural resources such as water and land, potentially reducing pollution per unit of input or output. However, they can also increase total resource use or boost yield per acre, leading to uncertain overall effects on pollution. These impacts will vary significantly across different fields, farms, and locations, as will the mechanisms through which these technologies change the effectiveness of input use and influence crop yields.

One such tradeoff is the rebound effect, where efficiency gains—instead of leading to decreased use of a resource—result in increased use due to the lower perceived cost. In agriculture, this could mean that improved efficiency from precision farming could lead to increased machinery use, energy consumption, and greenhouse gas emissions. A specific example can be seen in agricultural water management, where more efficient irrigation systems, supported by digital technologies like sensors, could lead to increased water depletion if not regulated by effective environmental policy. Water in agriculture is frequently underpriced, and the lower cost of precision irrigation systems could encourage investments in new irrigation systems. These systems could result in increased energy use as well as nitrous oxide emissions, offsetting the potential benefits from precision agriculture.[56]

Digital agriculture can also raise the marginal abatement costs, the cost of reducing an additional unit of pollution. Since precision technologies make inputs more productive at the margin, the opportunity cost of not using them in terms of forgone profits is higher.

The influence of digital agriculture on farm biodiversity is ambiguous. While it could support more diverse farms by enabling smaller plots, mixed cropping, hedgerows, and agro-silvo-pastoral systems, it could also reduce diversity and increase monoculture, as automation might be more efficient in more controlled systems with fewer variables. Unfortunately, there is limited empirical evidence on the environmental impacts of digital agricultural technologies, highlighting the need for more research in this area.

Below, we provide a deeper look into three climate-focused D4Ag solutions which hold particular promise for agricultural value chains in LMICs. Digital climate-smart advisory services, d-MRV, and digitally enabled agricultural and climate risk insurance.

[56] What's Cooking: Digital Transformation of the Agrifood System.

Solution Type	Examples	Reach & Adoption	Depth of Evidence for Impact	Headwinds
Digital Climate Advisory (Advisory & Information)	Agripredict APOLLO AGRICULTURE Digital Green			• Lack of agency • Unproven business models • Lack of access to quality & differentiated data
Digitally-Enabled Microinsurance (Financial Access)	eleaf WRMS Farm Smart. Secure Tomorrow. OKO Crop Assurance			• Poor ratio of operating costs to policy size • Sub-optimal farm-level data – practice & conditions • Limited financial literacy & awareness
Digital MRV Tools (Market Linkages & Access)	Transitry regrow Agreena			• Lagging quality of accessible data (spatial & temporal precision, 'baseline', local relevance) • Pricing opacity & unpredictability in markets • Shifting goalposts an underdeveloped frameworks • High costs and input-intensity in implementation

Low Mid High

Sources: Data-driven advisory services for climate-smart smallholder agriculture, GSMA, 2022;
Digital Measurement, Reporting, and Verification (MRV) for Climate and Land Use Impact: A Review of the Landscape, SustainCERT, 2022;
Agricultural and climate risk insurance for smallholder value chains: Identifying common challenges and solutions, IFAD, 2022.

Table 14. Examples of Digitally-Enabled Climate-Smart Agriculture Tools for Smallholder Farmers

Source: Feed the Future Flickr. Photo credit: Marta Rossinelli

Climate-Smart Advisory Services for Smallholder Farmers

Primary producers in LMICs require access to timely and accurate information to adapt and stay resilient to a changing climate. The urgency and complexity of climate change present challenges that traditional agricultural extension methods and generational knowledge may not adequately address. The rapidity of practice changes required in response to acute weather events, the unprecedented nature of climatic shifts undermining local knowledge, and the need for precision in decision-making necessitate a more advanced approach. This is where digital climate advisory services (DCAS) come into the picture: DCAS leverage one or a combination of technologies—such as weather forecasting tools, satellite imagery, soil sensors, and predictive modeling—to deliver timely and actionable insights directly to farmers. These services can provide advice on optimal planting dates, crop selection, pest management, irrigation scheduling, and more, all tailored to local climate conditions and future predictions.

Climate-smart advisory services have the potential to provide very comprehensive advisory services and not only guide daily decisions but also support larger shifts in farming practices toward climate-smart approaches. Our interviewees have highlighted several key challenges hampering adoption of DCAS in LMICs:

1. **Lack of Agency:** Smallholder farmers are often unable to act on the recommendations provided through digital advisories or other guidance systems. For example, farmers may be advised to select a drought-tolerant seed variety but find that they do not have access to those seeds in their local district. Or, they might be guided to implement alternate wetting and drying (AWD) in rice cultivation, yet lack the necessary funds or time to provide the required labor.

This emphasizes the importance of considering the "actionability" of recommendations provided to farmers. In the context of digital agriculture, the implication is that advisories must be mindful of the real constraints farmers face and possibly be bundled with complementary services such as access to finance, labor-matching, or input e-commerce. This integrated approach ensures that farmers not only receive recommendations but are also supported with practical means to implement them, aligning advice with accessibility and action.

2. **Unproven Business Models**: DCAS solution providers have largely struggled to monetize their offerings. This is particularly challenging in contexts where farmers are used to receiving advisory services for free or at a low cost, whether through traditional extension services, freemium offerings of corporate agribusinesses selling inputs and other services, through publicly subsidized advisory solutions, or otherwise. Furthermore, demonstrating the value proposition of these services to farmers and getting them to pay for premium features can be difficult, especially when the benefits of adopting climate-smart practices may take time to materialize.

   While it is challenging to monetize advisory services on their own, bundling approach is often successfully used by innovators to improve unit economics. By combining advisory services with providing inputs, access to agricultural markets, or access to finance, innovators are not only able to generate revenues, but also allow farmers to put the advisory into practice. On the other hand, subsided advisory-only services built in collaboration with donors and government extension agents remain a crucial tool for serving marginalized farmer groups in many LMICs.

3. **Lack of Access to Quality and Differentiated Data**: The effectiveness of climate-smart advisory services hinges on access to high-quality, granular, and context-specific data. This includes weather forecasts, soil conditions, crop performance data, and other agricultural data. However, there are significant gaps in the availability and reliability of such data, or the data that are available may not be sufficiently differentiated to reflect the diverse conditions and needs of different farms or regions. Several of the DCAS solution providers that were observed or interviewed in our study are primarily engaged in disseminating broad-based, relatively infrequent, and publicly available agronomic and weather-related advice. Despite the widespread availability of this information, it is not necessarily readily accessible to all stakeholders. Specifically, we heard from several providers that even such publicly generated data, like that emanating from national Bureaus of Meteorology, often presents challenges. This data can be difficult and/or costly to access and may be ill-suited for processing into customized and quality insights.

4. **Limited Collaboration Between Climate Change Experts and D4Ag Stakeholders**: For climate-smart advisory services to be effective, there needs to be a strong collaboration between climate change experts, who understand the science and implications of climate change, and D4Ag stakeholders, who understand the practical realities of farming and agricultural markets. This also includes integrating agricultural research into the services to ensure they are evidence-based and scientifically sound. However, in many cases, there is a disconnect

Source: Feed the Future Flickr. Photo credit: Md. Amirul Islam

between these two groups, leading to a gap between what the advisory services offer and what farmers actually need. Climate change experts are often focused on long-term global or regional climate trends and mitigation strategies, while D4Ag stakeholders are often more concerned with immediate, localized agricultural challenges. This misalignment can lead to a lack of practical, actionable advice for farmers.

Despite all these challenges, D4Ag innovators across LMICs are making significant headway in the delivery of climate-smart advisory services to smallholder farmers: Zambian **AgriPredict** is now reaching more than 90,000 smallholder farmers with their climate-smart agricultural extension services, weather information, and early warning system. Their unique feature lies in leveraging machine learning for crop disease diagnostics, providing targeted and efficient solutions to farmers' specific challenges. **Thrive Agric** (Nigeria) mainly focuses on connecting smallholder farmers with investors, but also offers personalized agronomy support, weather predictions, and pest/disease management recommendations. **Apollo Agriculture** (Kenya) offers a bundled service that combines financing, agricultural inputs, and customized advice. Their distinctiveness lies in using satellite data and machine learning models to provide hyper-local weather forecasts and tailored agronomic advice. **AgroStar** (India) is notable for its mobile app-based platform that allows farmers to purchase agri-inputs, receive customized agricultural advisory, and connect

with other farmers. The use of data analytics to offer specific recommendations based on specific data inputs like their soil quality and water availability. **Greenovator** (Myanmar) offers farmers access to weather forecasts, market prices, and expert advice; and has built a unique community approach connecting farmers to foster knowledge sharing and collaboration.

Together, these innovators demonstrate a diverse array of approaches and technologies, reflecting the multifaceted nature of climate-smart agriculture. Their common goal, however, is to provide smallholder farmers with the timely, relevant, and actionable information they need to adapt to and thrive amid changing climate conditions.

Digitally Enabled Measurement, Reporting, and Verification (d-MRV)

Monitoring the progress of climate-smart agriculture initiatives is crucial for understanding their effectiveness and guiding future interventions. Conventional monitoring, reporting, and verification (MRV) approaches have proven to be hard to scale in the LMICs context due to the need for expensive site visits for constant data collection, as well as rigorous reporting and verification.

d-MRV systems present an opportunity to unlock significant value within the agriculture and environmental sectors, especially by diversifying and amplifying revenue streams for primary producers. This involves not only an immediate financial gain for farmers and agricultural businesses but also contributes to broader societal goals such as environmental restoration and climate change mitigation. The integration of d-MRV systems within agricultural practices can facilitate more accurate tracking and reporting of greenhouse gas emissions and removals, aligning economic incentives with sustainable land management practices.

Recent shifts in public perception and regulatory scrutiny are also driving demand for more rigorous and transparent carbon projects, and d-MRV solutions can respond to this challenge by providing more accurate and verifiable data, thereby enhancing the credibility and cost efficiency of higher-quality projects. This enhanced rigor not only meets the demands of a more discerning market, but also ensures that environmental benefits are realized in a manner that is both socially equitable and scientifically sound.

Digital MRV systems can provide reliable, accurate, and timely data on key climate and agricultural parameters. This data can be used to measure the impact of interventions, track progress toward climate and agricultural goals, increase trust and transparency, as well as speed up the payments for carbon credits. Digital technologies can also help streamline data collection and reporting processes, making them more efficient and cost-effective. For instance, remote sensing technologies, such as drones or satellites, can provide detailed and regular data on land use, crop health, and weather conditions. Blockchain technology can ensure data integrity and traceability, while AI and ML algorithms can analyze large volumes of data to detect patterns and trends.

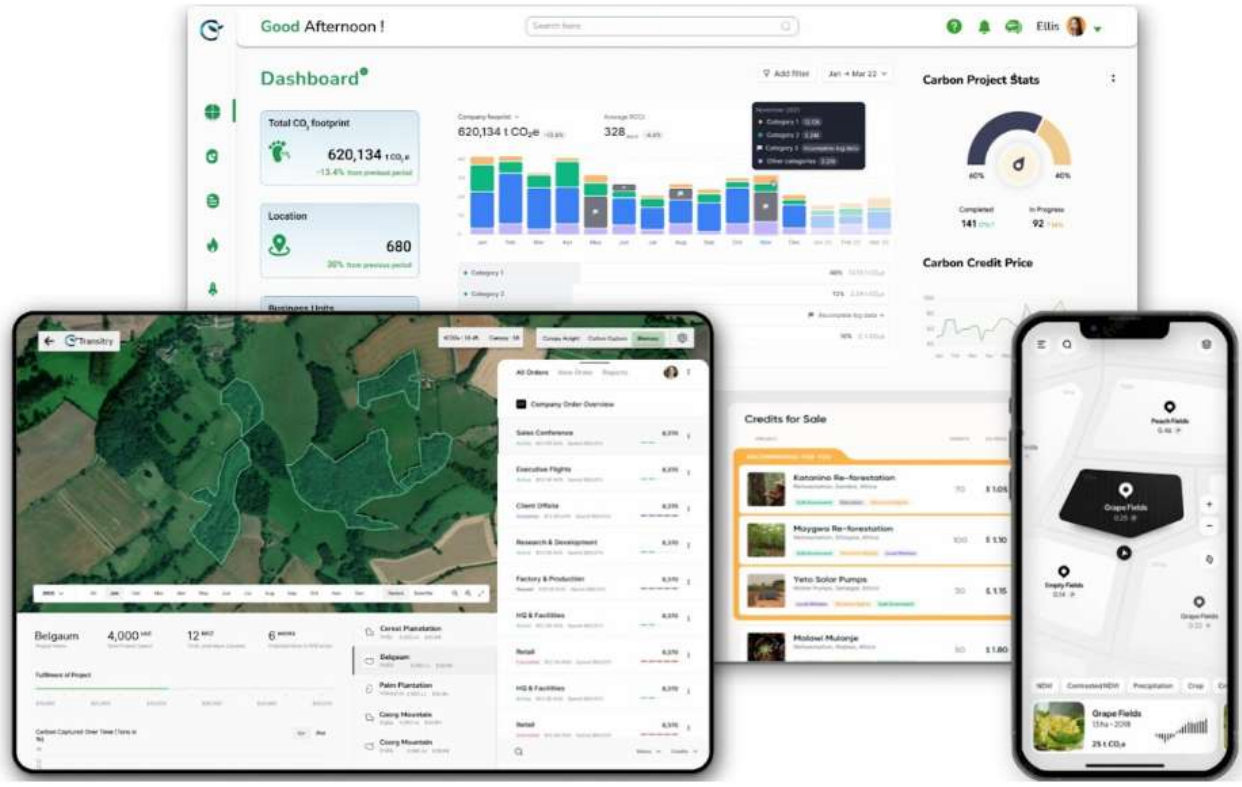


Figure 52. Example of d-MRV platform interface.
Source: Transitry

Companies like **Transitry** (Singapore), **Agreena** (Denmark), and **Regrow Ag** (USA) are all leveraging digital technology to monitor and verify sustainable agricultural practices, facilitating access to agricultural carbon markets, with, however, limited applications in LMICs. **Transitry** specializes in using AI, satellites, and smart sensors for d-MRV: After scanning project areas with satellite imagery, they apply their proprietary AI algorithms to monitor carbon sequestration effectiveness. They claim that their technology has achieved a 95% accuracy and is 10x cheaper and 60x faster than the conventional soil sampling method. **Agreena** creates access to an additional revenue stream for farmers through carbon certificates based on climate-friendly farming practices. After the harvest season, farmers report their actual yields, as well as fertilizer and fuel use, and are issued with verified CO2e q certificates that they can sell on the platform. **Regrow Ag** is working with agribusiness, retailers, and CPGs to provide "resilient agriculture" solutions. Its transparent reporting, historical analysis, and forward-looking projections of carbon sequestration and emissions reductions allow stakeholders across the emerging ag carbon credits industry to create, and cash in on, carbon strategies.

Early deployments of d-MRV solutions have been primarily focused on afforestation and deforestation monitoring, as well as soil organic carbon tracking. These efforts mainly target carbon sequestration, leaving significant gaps in addressing other key agricultural emissions like methane and nitrous oxide. The limited scope of current d-MRV services in these regions

can be attributed to several factors such as high upfront costs, complexity of modeling, hardware and software challenges, lack of available ground-level data, and shortage of skilled personnel (specifically in data analytics, software development, environmental science, and carbon standards knowledge). Additionally, the lack of appropriate methodologies, measurement technologies, and specific data to perform the measurement and verification processes contributes to the current narrow focus, neglecting major emission sources in agriculture.

In our conversations with stakeholders, some serious challenges around ground-level data have surfaced that currently hamper the deployment of effective d-MRV services. Despite remote sensing being a crucial and valuable data source, it is not sufficient on its own: remote sensing requires validation with ground-level data, essential for accuracy. The real value for farmers springs from comprehensive, field-specific data that enables the construction of detailed, pragmatic models. This type of information encompasses local weather trends, soil conditions, and crop-specific data, all unique to each farm's circumstances. The absence of such granular, hyper-localized data presents a substantial barrier, stymying the deployment of scalable, transformative D4Ag solutions.

Moreover, there is a pressing need for extended, localized agricultural emissions studies. As pointed out by our interviewees, to develop accurate models and assessments, it is necessary to have comparative, multi-year studies contrasting farms that have adopted climate-smart practices with those that have not. The current lack of such comparative datasets complicates effective model calibration. Without this calibration, the risk emerges that solutions may become unscalable and overly dependent on manual data collection.

> *"We do not have enough data to provide these tools d-MRV, and we actually need government and non-profit support. This is how we usually think about being able to reach into new geographies that have smallholder farmers, low- and middle-income countries because in countries where we are getting commercial traction, we don't don't have to do that. So we are a lot more dependent on the priorities of governments [in LMICs]"*
>
> d-MRV startup founder, Australia

> *"The biggest constraint that we found [for supporting d-MRV] was a lack of capacity within the government and, obviously the cost of getting good ground-level data."*
>
> NGO, the Netherlands

Moreover, there is a clear lack of evidence about the efficiency, accuracy, and impact of d-MRV: Even though d-MRV promises the facilitation of more cost-efficient and higher-quality carbon projects, "in effect, it presents itself somewhat opaque and inconsistent. Many credibility claims from tech developers and innovative startups are difficult to assess today, as broad independent validation for a wide range of species and conditions seems lacking for many of the new approaches."[57]

In summary, there is a clear need for high-quality, granular, and localized data, as well as new studies, and overcoming these data challenges will be key to unlocking the full potential of climate-smart advisory services and d-MRV solutions.

Digitally Enabled Agricultural and Climate Risk Insurance

Insurance is a powerful tool for managing risk, and in the context of agriculture, it can protect farmers against the financial losses caused by climate-related events such as droughts or floods. However, traditional insurance models often struggle to reach smallholder farmers due to high costs, lack of data, and logistical challenges: according to GIZ, "approximately half [of the farms in LMICs] had some insurance coverage in 2020. However, about 310 million of these farms were in China and India, which means that approximately 80% of farms in these two countries had insurance, while only about 10% of farmers (13.3 million) in other LMICs were insured."[58]

	Africa	China and India	Rest of Asia	South America
% Insured Farmers	1.5%	95%	3.1%	0.4%
% Land Covered by Agricultural Insurance	0.1%	96.3%	1.5%	3.1%

Table 15. Agricultural insurance coverage in LMICs
Source: GIZ, 2021

Digital technologies can address these challenges by enabling innovative, scalable, and cost-effective insurance solutions. For instance, satellite imagery and weather data can be used to develop index-based insurance products, which trigger payouts based on measurable environmental parameters (like rainfall levels) rather than individual loss assessments. Mobile money platforms can facilitate premium payments and claims disbursements, making the process more accessible and efficient for smallholder farmers.

Innovators like **Weather Risk Management Services** (India), **OKO** (Mali), and **eLEAF** (the Netherlands) are at the forefront of developing digitally enabled agricultural and climate risk insurance solutions for smallholder farmers. WRMS uses a combination of remote sensing technology, weather data, and predictive modeling to provide the world's first income guaranteed smart and sustainable farming solution applicable to farms of all sizes—SecuFarm. Mali's OKO leverages mobile and satellite technologies to provide affordable, accessible crop insurance to smallholder farmers, even in remote locations. As of July 2022, OKO

[57] Assessment of Digital Measurement, Reporting, and Verification: A Snapshot of D-MRV in Decentralized Energy, Forestry, and Agriculture. White Paper. Climate Ledger Initiative, 12 July 2022

[58] Innovations and emerging trends in agricultural insurance for smallholder farmers – an update. GIZ, 2021

has insured more than 18,500 farmers, making OKO the most popular crop insurance product in the country. eLeaf applies satellite imagery and agronomic models to provide data-driven crop index insurance solutions, and it works with a wide range of clients besides farmers' cooperative: governments, financial institutions, insurers and reinsurers.

In Kenya in 2008, Syngenta Foundation for Sustainable Agriculture, UAP Insurance, and Safaricom offered the first digitally enabled insurance for smallholder farmers—**Kilimo Salama**. Using automated weather stations and mobile payouts allowed for lower costs and affordable premiums for smallholders, as there was no more need for expensive farm visits. After having insured 187,000 farmers in three countries by 2014, Kilimo Salama evolved into a for-profit company **ACRE Africa** that now links farmers to insurance products in Kenya, Rwanda and Tanzania, Uganda, Ghana, Malawi, Senegal and Mozambique. This was the first example in the history of the Syngenta Foundation that a project spun off to become a company, demonstrating the potential of digitally enabled insurance for smallholder farmers.[59]

However, digitally enabled insurance providers are facing a similar set of challenges when scaling up their services in LMICs, such as lack of awareness, trust and understanding of products among end users; lack of ability and/or willingness to pay; absence of adequate data, as well as poor distributions channels for their products.[60]

While a significant portion of the current focus is centered on carbon and emissions management, the scope of climate-smart agriculture goes beyond this and includes aspects such as water management, soil management, air quality and pollution, waste management including plastics, and biodiversity. Particularly, "water management" is emerging as a significant challenge given the widespread dependency on rainfall, increasing prevalence and frequency of droughts in certain regions, and water-intensity of principal food crops such as rice.

Source: Feed the Future Flickr. Photo credit: Nicolas Réméné, OKO

[59] Agricultural insurance - East Africa - Syngenta Foundation

[60] Agricultural and climate risk insurance for smallholder value chains: Identifying common challenges and solutions. IFAD, 2021

	CHALLENGES		POTENTIAL SOLUTIONS
Demand Side			
1	Lack of understanding of risk management needs, constraints and patterns of smallholder farmers		Conduct agricultural value chain risk assessments
2	Limited awareness, understanding and trust of insurance		Develop education in risk management and insurance; assess the value of insurance options to clients and integrate measures that foster trust
3	Lack of ability and willingness to pay		Assess and set up alternative scheme-sand payment arrangements; test prices and adjust contract options
Supply Side			
4	Lack of adequate insurance products available		Assess, develop and test: finance feasibility assessment studies for specific, targeted insurance schemes; support design, testing and roll-out of an insurance product
5	Constrained capacity of public insurers		Deliver focused training and coaching to insurers
6	Lack of suitable distribution structure or delivery channel in place		Set up or expand schemes using trusted delivery channels
Enabling Environment			
7	Adequate risk data are not available, not of the required quantity or quality, or are expensive to get for index insurance purposes		Fund public data collection, management and provision (including weather, yield, livestock and remotely sensed data)
8	The enabling environment is not conducive to the development of agricultural and climate risk insurance options for smallholder farmers		Provide support to government for the setting up or implementation of agricultural insurance products and schemes

Source: IFAD, 2022

Figure 53. Challenges & Solution for Digitally-Enabled Agri Insurance in LMICs

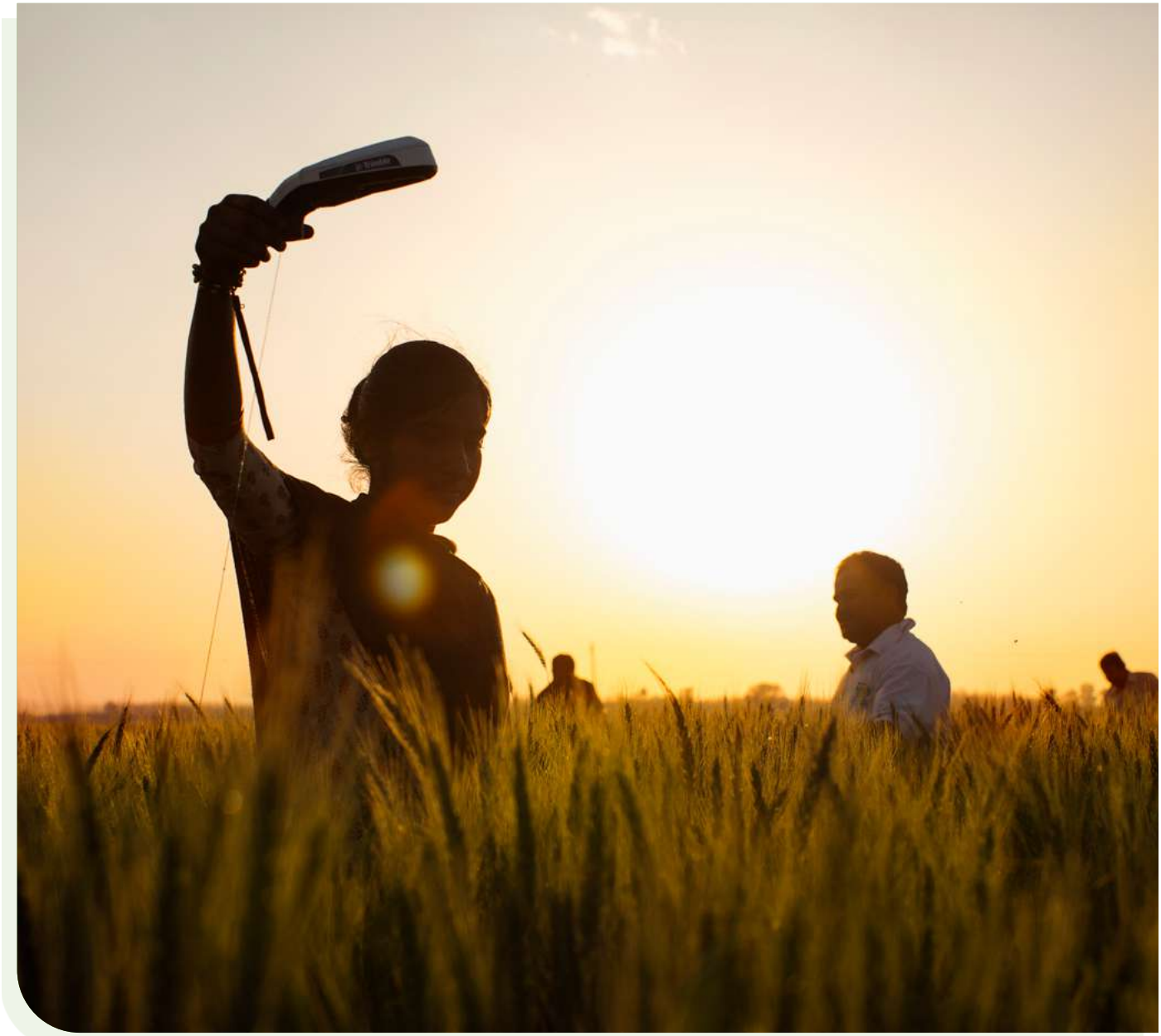
Chapter VIII:

Future Outlooks and Recommendations

Thus far, this report has aimed to lay out the current state and shifting dynamics for the D4Ag sector in LMICs. In this section, we turn to what the future of the sector holds: the primary challenges with which stakeholders across the D4Ag ecosystem will continue to contend, the forward-looking trend in which we are most confident, and the alternative futures—both positive and negative—which could come to bear for the sector over the next decade. It is critical to recognize the agency that different actors across the D4Ag ecosystem—whether innovators, producers, policymakers, investors, agribusinesses, donors, or otherwise—will play in the realization of a "thriving" global D4Ag sector.

CRITICAL CHALLENGES ACROSS THE SECTOR

Peppered and alluded to throughout the preceding chapters, we have consolidated and organized the most critical challenges constraining the development of inclusive, climate-smart, and commercially viable D4Ag ecosystems across LMICs.



Source: Feed the Future Flickr. Photo Credit: Daljit Singh

Disconnected Knowledge-Sharing and Collaboration Networks	• Underutilization of traditional knowledge-sharing and support networks • Lack of North-South and South-South learnings between D4Ag actors • Lack of coordination, alignment, and cross-learning in donors' D4Ag efforts • Lack of engagement and knowledge sharing on D4Ag between governments
Uncertainty of Financial Viability	• Concentration of funding in few countries, use cases, and even individual D4Ag innovators • Limited track record of successful exits and later-stage investment • Persistent financing gaps in categories such as accessible working capital, short-term debt, and smaller-scale fundraising pathways • Lack of accessible and transparent data on early-stage solutions • Cherry-picking of winners and losers by donors
Poor Accessibility and Quality of Physical and Digital Infrastructure	• Shortcomings in public data quality, comprehensibility, and integrity • Duplication and disconnectedness of primary data capture • Disproportionate focus on cropping value chains (relative to livestock, aquaculture, and other production systems) • Lack of common data standards and taxonomies, including categorizing D4Ag solutions • Persistent under-investment in fit-for-purpose D4Ag middleware • Limited access and affordability of reliable mobile networks and devices
Shortcomings in User Engagement and Market Penetration	• Digital fatigue at the end-user level • Limited access to user support and capacity-building programs • Shallow understanding of target markets by innovators and value chain partners
Lack of Quality Impact Measurement	• General inattention by funders and innovators to potential adverse impacts of D4Ag • Persistent gap in evidence regarding D4Ag impact for different end users facing different challenges • Fragmented landscape of impact metrics • Time, cost, and knowledge-related constraints to quality impact measurement
Persistence of Gender Inequality and Social Exclusion	• Lagging D4Ag penetration among marginalized sub-populations (where even assessed) • Lack of market-driven incentive and accountability for "inclusion" as an outcome • Disproportionate burden of effort associated with D4Ag use by women and youth • Persistence of "hidden" users (particularly, but not limited to, women) • Lack of sex-disaggregated data across D4Ag product life cycles • Poor representation of women across the D4Ag ecosystem—including base of innovators and investors • Lack of common indicators and evaluative frameworks for GESI impact from D4Ag
Constraints to Climate-Smart D4Ag Deployment and Credibility	• Lack of appropriately detailed, practice-specific, and localized data on emissions mitigation and sequestration in agriculture • Under-development and -maintenance of public agriculture sector data • Absence of clear and trusted policies and standards for generation, management, and marketing of carbon credits (public and private mechanisms) • Continued "greenwashing" by companies and investors • Limited evidence linking D4Ag directly to climate outcomes • Lack of business models merging long-term climate outcomes to short-term farm-level decisions

Table 16. Critical Challenges across the Sector

If the past decade is any indicator, we can be quite certain that the D4Ag sector is likely to see continued and substantial evolution over the next five to 10 years. There are a few forward-looking trends around, which we have a particularly high degree of confidence will bear fruit—whether considering incremental progress in the development of D4Ag ecosystems' "foundational" elements, macro dynamics, or business model trajectories. In addition, there are a number of trends and trajectory-shaping outcomes for which our foresight and predictive powers are less-suited: alternative futures reflecting interconnected choices by D4Ag ecosystem stakeholders in coming years to determine whether and at what pace D4Ag ecosystems are "derailed" or "thrive." This section will elaborate on both these aspects of future outlooks for the D4Ag sector, including the presentation of a loose quantification of the magnitude of impact that is "at risk" from mismanagement, collectively, of the D4Ag sector.

FORWARD-LOOKING TRENDS

There are a few directions in which we are highly confident D4Ag ecosystems will evolve given historical trends, expert perspectives, committed investments and policies, and market conditions/realities.

Ecosystem Foundations	
Smartphone Accessibility	As technology and internet accessibility continue to improve, we can expect nearly ubiquitous smartphone and 3G+ connectivity in the coming decade. This trend will enable more farmers and stakeholders to access digital tools, bridging information gaps, and fostering digital literacy in agriculture.
Regulatory Evolution	As the sector matures, new regulations and policies introduced by LMIC governments will likely guide or stimulate D4Ag development. These regulations have the potential to foster a more structured ecosystem, ensuring accountability, ethical practices, and alignment with national goals and international standards.
Climate Change Integration	As public and private sector actors face increasing pressure regarding, and focus more squarely on tackling, climate change, the D4Ag sector will become more closely entwined with the 'ClimateTech landscape. In many cases, D4Ag tools will be integrated and advanced as critical tools in the measurement and management of carbon and other components of environmental sustainability. Innovations in climate-smart D4Ag will be increasingly used to promote sustainable practices and foster resilience across the value chain.
Market Dynamics	
Divergent Trajectories	We can anticipate a continued divergence in trajectories between enterprise and farmer-facing D4Ag in aspects such as investor bases, pace of growth, and commercial viability. This divergence might result in farmer-facing D4Ag remaining sub-scale in some ways, perhaps by design, limiting direct impact on individual farmers.
Volatile Market Dynamics	The sector may witness both meteoric rises and falls. The emergence of D4Ag unicorns and the possibility of significant failures underline the risk and reward dynamics of the sector, shaping investment strategies and market behavior.
Expansion in Emerging Markets	We can expect a "re-acceleration" of D4Ag startup expansion, especially in emerging markets that are beginning to demonstrate growth. Expansion into new markets will allow for greater diversification and adaptation to unique regional challenges and opportunities.

Continued Relevance of "Point Solutions"	Point solutions will remain relevant, addressing a wide range of unaddressed challenges with substantial total addressable markets (TAM). Specific, targeted solutions will foster innovation and efficiency within specific niches, with phygital (physical plus digital) approaches continuing to be vital.
Business Models	
Business Model Innovation	While technological innovation remains important, business model innovation will likely open up new waves of opportunity for D4Ag, including new revenue streams, financial products, and intermediary models that foster growth and sustainability within the sector.
'Digitally Native' Agribusinesses	The emergence of "digitally native" corporate agribusinesses along the value chain is predicted, with AgTech startups potentially evolving into new "majors," creating more dynamic and efficient value chains, driving technological adoption at all levels of agriculture.

Table 17. Forward looking Trends

Photo Credit: Brastorne

ALTERNATIVE FUTURES

Above, we mapped some of the forward-looking trends that we are most confident will be realized going forward. For all the historical evidence observed and conveyed to us, though, we recognize that the realization of potential benefit drawn from D4Ag across LMICs will be shaped by a range of decisions and actions made by myriad stakeholders in myriad D4Ag ecosystems, which are not foregone conclusions. Runaway technological progress, economic volatility, political instability, shifting consumer sentiment, idiosyncratic adverse events, and other socioeconomic and cultural influences are sure to solicit a range of responses—from policymakers, funders, agribusinesses, innovators, and producers themselves—which accelerate, constrain, or alter the shape and impact of D4Ag innovation.

In this section, we aim to visualize divergent global trajectories for the D4Ag sector could unfold over the next 10 years, and the implications this could have for the agricultural sector in LMICs writ large. These "alternative futures" are an attempt to convey the cumulative risks involved in specific actions, or inactions, by actors across the D4Ag ecosystem.

In reality, we are well aware that the range of trajectories and outcomes for the D4Ag sector and agriculture in LMICs in general are infinite and complex. This exercise is not intended to be one of precision, but rather an opportunity to show the magnitude of impact at stake when considering the development of the D4Ag sector, over the next decade and beyond. Thus, we lay out, in qualitative and quantitative terms, what might be the implications of "good" versus "poor" management of the sector on development outcomes—economic, social, and environmental—at sector- and stakeholder-levels.

In broad terms, we have sketched out two scenarios reflecting "opposite" ends of the outcome spectrum:

1. The "**derailing**" scenario: in this scenario, we are framing what we consider to be a "lower bound" of the growth and impact curve for D4Ag across LMICS. This does not envision a sharp reversal of D4Ag sector growth, which would be truly antithetical to the study and learnings we have conveyed to this point. Rather, the "derailing" envisions a general "plateau" and stagnation where D4Ag sector growth has taken off to date, and a lack of "liftoff" most everywhere else. The forward march of technological progress is largely unabated, but unintended consequences, ill-effects, and novel risks are largely unanticipated and unaddressed by those deploying, disseminating, funding, or even (especially) regulating them. While individual innovators may not be deterred, a prolonged economic downturn and promising opportunities in competing industries push private investors to limit exposure to the D4Ag sector, and public / philanthropic funders do not move in to fill the gap. The bulk of D4Ag innovation supply remains the domain of few limited at-scale actors, who are invested in sustaining advantage to a relatively narrow set of production systems and traditional, sometimes environmentally harmful, forms of production. Devoid of data-driven standards, enabling infrastructure, and funder scrutiny, persistent innovators focused squarely on business survival lack will and/or capability to prioritize social and environmental impact alongside business economics, so "low-hanging fruit" is the only segment of adoption to get picked. Poor data governance and digital infrastructure open the way for data breaches, discriminatory practice across the value chain (at cost to farmers), and malicious actors. Negative

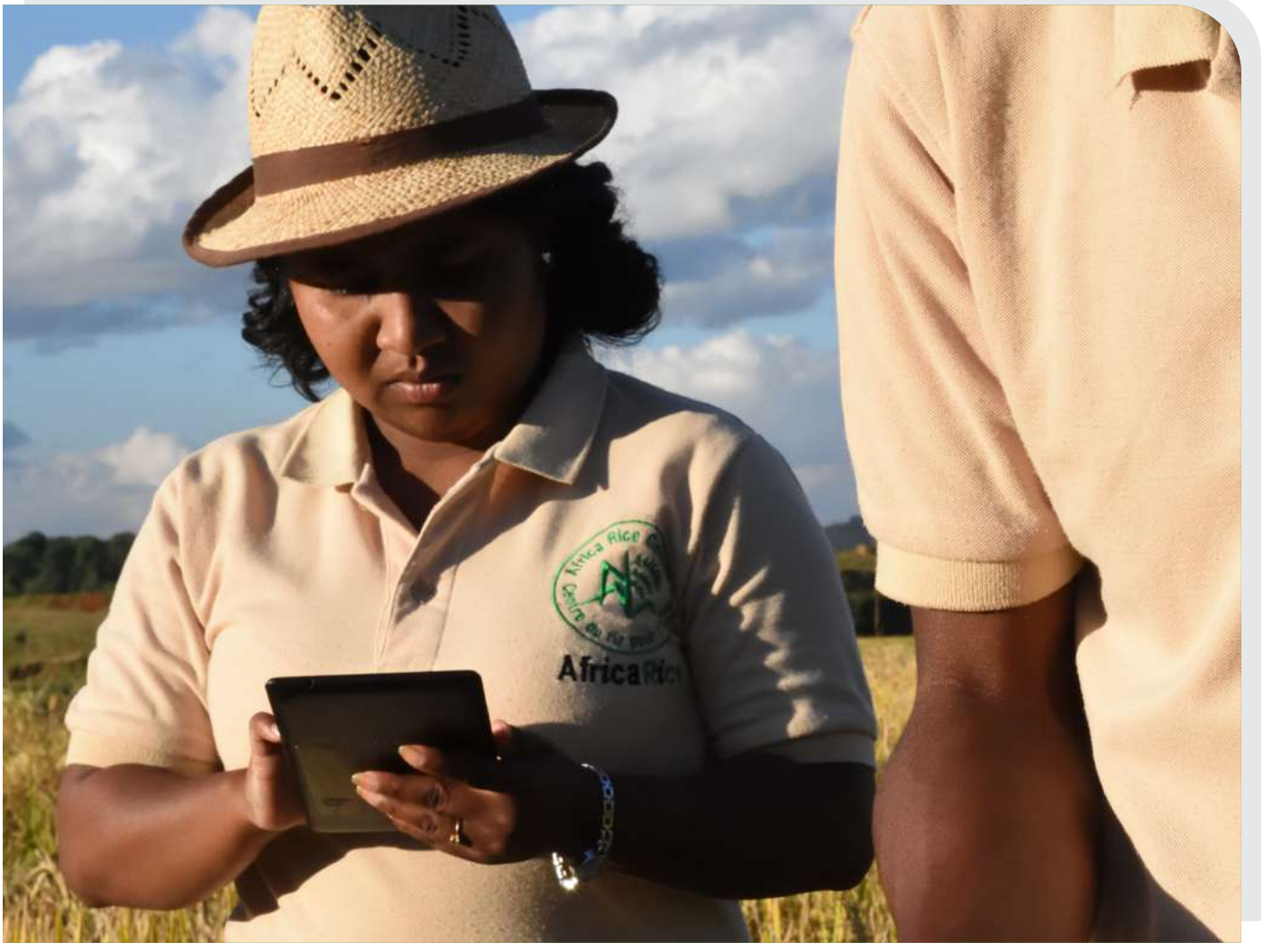
press and misinformation fuels antipathy to D4Ag, sowing distrust and reversion.

2. The "**thriving**" scenario: In this vision, we encapsulate what we envision as the "upper bound" of the growth and impact curve for D4Ag across LMICs. This is not a mere projection of our present course, but a portrayal of D4Ag reaching its zenith. In this context, growth is not merely sustained—it thrives, with emerging and nascent D4Ag ecosystems learning and building off the example of "leaders" and finding ways to "lead" in their own right. This success is built on collaboration, foresight, capacity building, and smart policymaking. Investor confidence in the sector is sustained through economic downturn through persistence of public and social sector co-investors, provision of bridge and alternative financial support, and notably celebrated "success stories" from D4Ag pioneers. The key to D4Ag's widespread uptake is its inclusivity—in its design, development, and dissemination. Buoyed by market signals and incentives, fit-for-purpose standards and support, and a drive to push adoption beyond the "low-hanging fruit" encourages D4Ag innovators to engage deeply and locally with end users. Local wisdom is integrated, adding depth, nuance, and alternative pathways to digital solutions. D4Ag is enlisted as a tool by public and private sectors in making, monitoring, and sticking to commitments surrounding climate change and environmental sustainability. Universities, training institutes, and ecosystem builders seize on the opportunity to power an energized, motivated, and capable force of new D4Ag champions to further drive the sector forward. Support from the private sector grows, as agribusinesses seek ways to mutually benefit alongside locally and regionally relevant D4Ag innovators and extend holistic digital/physical solutions to end users across the value chain. Government and philanthropic players, seeing increasingly well-documented benefits from D4Ag and the positive-value collaboration the sector is driving across D4Ag ecosystems, increase their involvement, driving more collaboration and shared resources. Trust anchors this success. Strong data governance and open communication tackle misinformation and ensure privacy. D4Ag tools evolve from being just tools to trusted partners, working alongside farmers to boost agricultural success and sustainability.

Aspect	"Derailing" Scenario	"Thriving" Scenario
Livelihoods	**SHFs are "down and out"** • Persistent decline in real wages and income from on-farm production • Aging population struggle with complexity and challenge of D4Ag adoption • Exodus of younger generation leaving agriculture for other more lucrative and tech-intensified industries	**SHFs are "up and in"** • Growing class of digital-savvy farmers adopting D4Ag swiftly • Smallholder producers extract value from production in diverse ways • High degree of risk awareness, mitigation, and resilience
Innovation	**Innovation is "stifled"** • Innovation in isolation, geographically and socially • Talent crunch, high competition, and costs • Agricultural R&D investment downturn • Nascent and early emerging D4Ag ecosystems stagnate	**Innovation is "distributed"** • Near ubiquity in uptake for basic D4Ag solutions, and proven pathways for growing sophistication and expansion of adoption • Innovators are leveraging proven pathways and partnerships to expand services to regional and global markets • Decentralization of D4Ag "hubs"—i.e., centers of innovation for distinct corners for the globally industry in more LMICs • Universities and vocational institutes across LMICs sustaining a continued pipeline of D4Ag innovators and end users, and creating pathways from "research" to "action" and "enterprise"
Environment	**Environmental "degradation"** • Data-driven input intensification (i.e., chemicals, fertilizer, water) putting pressure on local ecosystems and biodiversity • Proliferation of poor quality carbon projects delivering poor GHG emissions reduction returns	**Environmental "regeneration"** • Accelerated uptake of locally applicable and actionable climate-smart agriculture practices • Public sector and research agencies leveraging—and supporting fit-for-purpose development of—D4Ag tools to set environmental goals, monitor progress, and drive (i.e., monetary) support to contributors • Emergence of D4Ag solutions purpose-built for (bio)diverse production systems and value chains
Culture	**Erasure of indigenous knowledge and practices** • Sidelining of traditional methods in digital solutions • Disruption of traditional knowledge transmission pathways • "Forgetting" culturally specific resources, assets, and practices	**Cultural safeguarding and enrichment** • Targeted and place-based user engagement is a foundational "right to play," rather than "nice to have" for active D4Ag innovators • Locally deployed D4Ag tools are built with cultural and social norms of end users in mind, from UX/UI design to data inputted and generated
Inclusion	**Systematic barriers to gender & social inclusion** • Data-driven discrimination baked into core value chain activities (i.e., financing, marketing, and employment)	**Equitable access and benefit for all** • Proliferation of D4Ag solutions tailored for challenges facing specific social strata (i.e., women, people living with disabilities, ethnic minorities, elderly) and their intersections

Aspect	"Derailing" Scenario	"Thriving" Scenario
Digital Foundations	**Expectation of exploitation** • Reduced trust in digital tools through rampant, unchecked misinformation and false claims • Rise in data privacy breaches and identity thefts, with catastrophic economic impacts for end users and intermediaries • Lack of political engagement with challenges of D4Ag data, instead resorting to broad-based restriction of digital solutions and data access	**Shared stake and mutual benefit** • Diverse stakeholders share data strategically, responsibly, and nimbly through established best practices • Farmers are effectively and collectively drawing continual returns from ownership and monetization of data use for and generated by D4Ag solutions • Public and private sectors are leveraging D4Ag tools to drive strategic, resource allocation, and evaluative decisions

Table 18. Potential Scenarios for D4Ag



Source: Feed the Future Flickr. Photo credit: Rakotonantoandro Lalaina

Such divergent outcomes for LMIC agricultural sector at large imply a parallel divergence in potential outcomes for the individual stakeholdewrs comprising D4Ag ecosystems.

CLIMATE-SMART ADVISORY SERVICES FOR SMALLHOLDER FARMERS

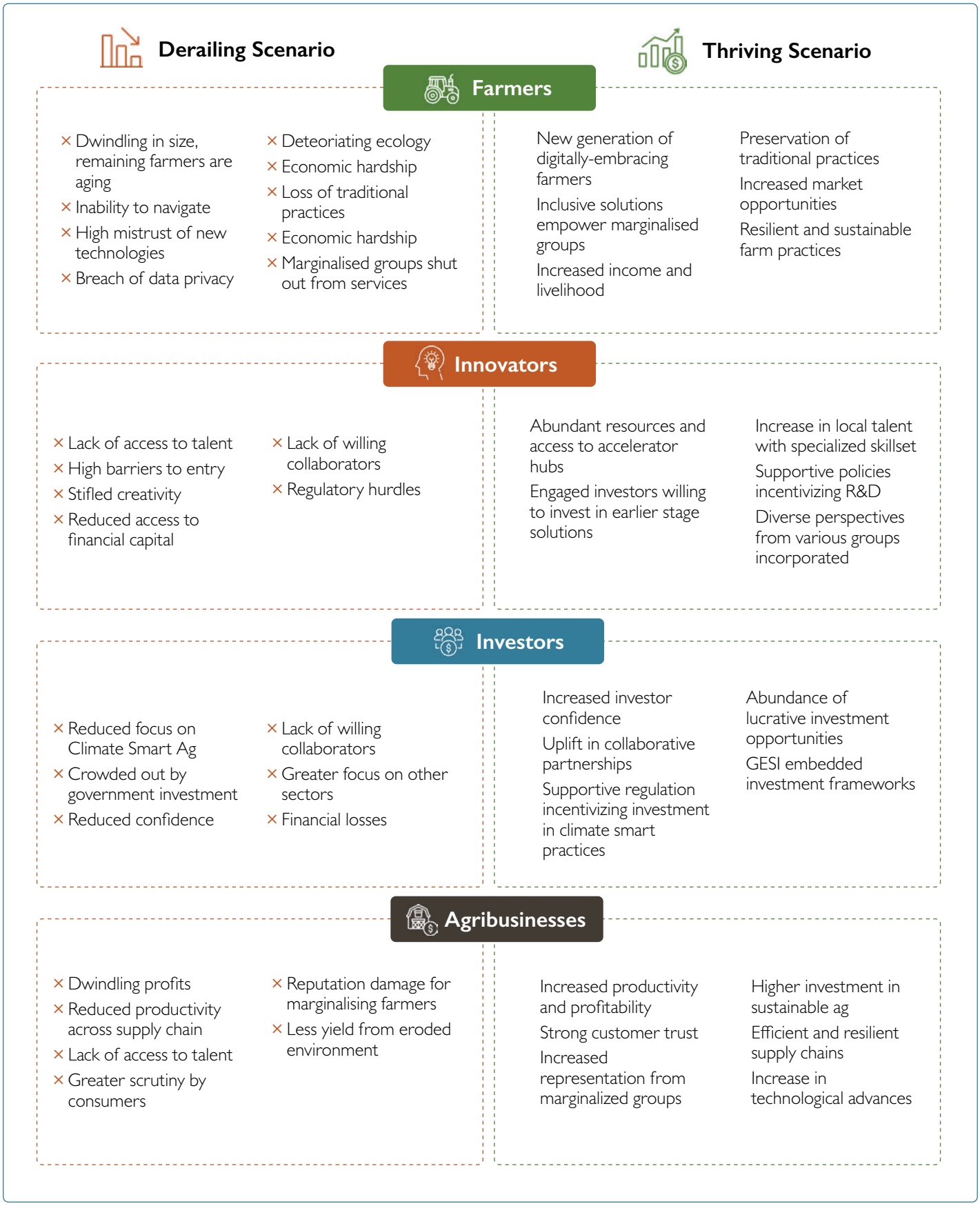


Figure 54. How Key Stakeholders Across the Agriculture Sector in LMICs Are Affected

BY THE NUMBERS

Continuing from the two alternative futures—"thriving" and "derailing"—this section attempts to quantitatively model the potential impact of D4Ag across LMICs over the next decade across three critical dimensions: Economic, Environmental, and Gender Equity and Social Inclusion. The purpose of this exercise is not to achieve precision, but rather reflect on the magnitude of difference in outcomes when D4Ag sector development goes "right" versus "wrong." It is important to emphasize that the "thriving" scenario will not unfold organically through government and organizations' "business as usual" operations, but rather through an intentional and planned set of actions. The "derailing" scenario attempts to quantify those potential unforeseen consequences of D4Ag. As a reminder, the impact quantified in the following sections focuses on that which is enabled by D4Ag tools.

We have focused on projecting out a few key metrics (see below) for each dimension to represent at a high level the extent of impact D4Ag will have not only from a global LMIC perspective, but also from a regional perspective (See Appendix 5).

- **Economic**: Net income increase enabled by D4Ag tools
- **Gender Equity and Social Inclusion**: Farmer D4Ag adoption rates; female inclusion in D4Ag tools
- **Environment**: Change in farm-gate GHG emissions enabled by D4Ag tools

Source: Feed the Future Flickr. Photo Credit: Daljit Singh

Global view

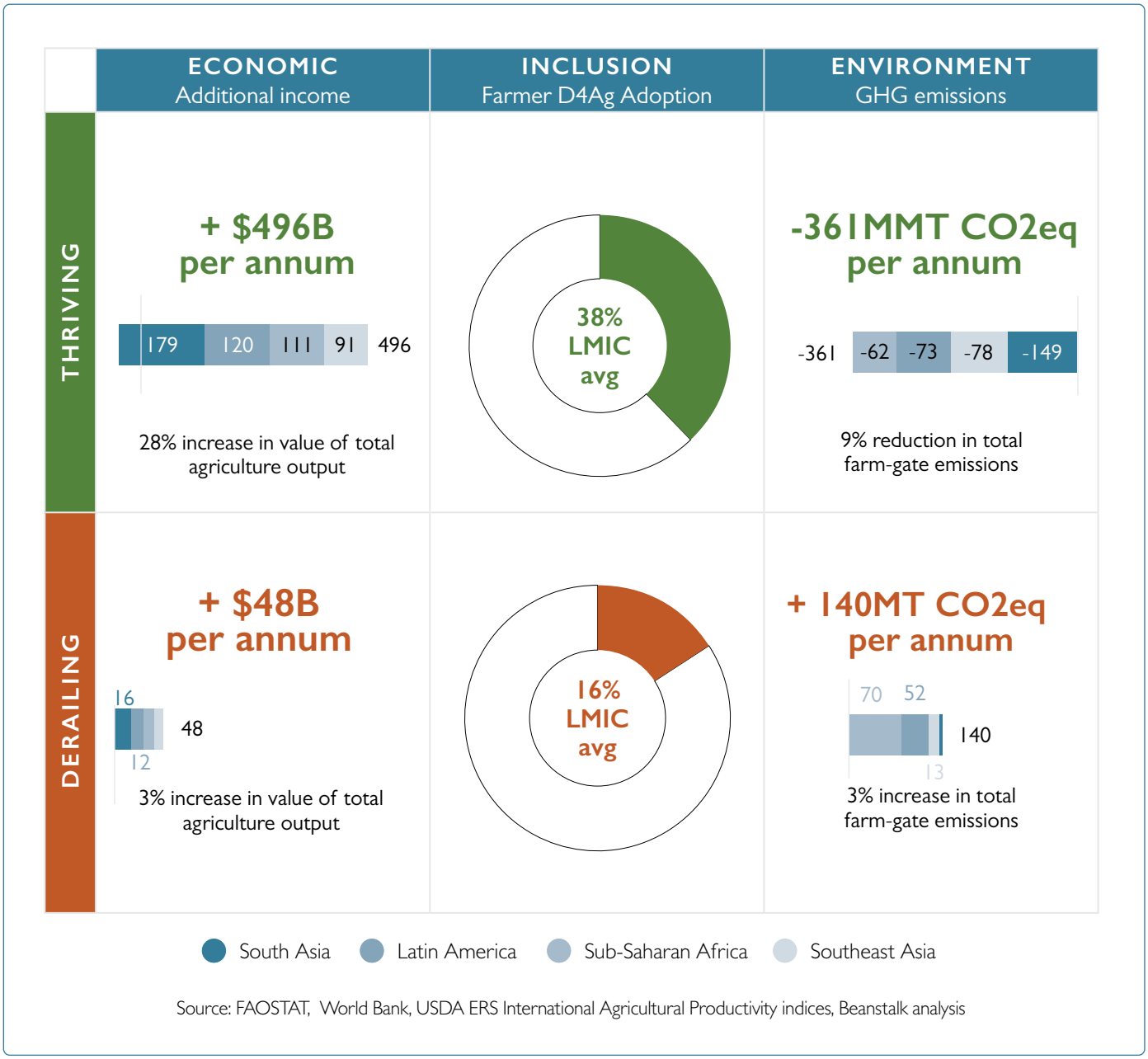


Figure 55. 10-Year Outlook of Impact Outcomes Enabled by D4Ag Tools Across LMICs

Our 10-year outlook estimates that by 2033, achievement of the "thriving" D4Ag scenario could add US$ 496 billion of additional value per annum across LMICs, representing an increase of 28% of agricultural output across focus regions. In the "derailing" scenario, only a fraction (~10%) of potential D4Ag enabled income is captured at US$ 48 billion.

When "thriving," D4Ag adoption will more than quadruple to 38% as farmers flock to effective D4Ag solutions. Alternatively, if lack of trust in D4Ag solutions is amplified, uptake may severely plateau in the next decade to only 16%.

Lastly, there is huge potential for D4Ag to create greater efficiencies and reduce

farm-gate GHG emissions by 9% (-361 Megatonnes CO2eq per annum). An unintended consequence that D4Ag may have on the environment is contributing to an increase in GHG emissions (+140 Megatonnes CO2eq per annum).

From an economic perspective, we have identified six key income levers that are enabled by D4Ag tools.

1. **Reduced crop and animal loss:** One of the largest losses of agriculture value is low crop yield and animal mortality. Many LMIC have large yield gaps, with many regions only producing 10–20% of their full potential for certain crops. (Examples of enabling tools: precision agriculture advisory and smart irrigation.)

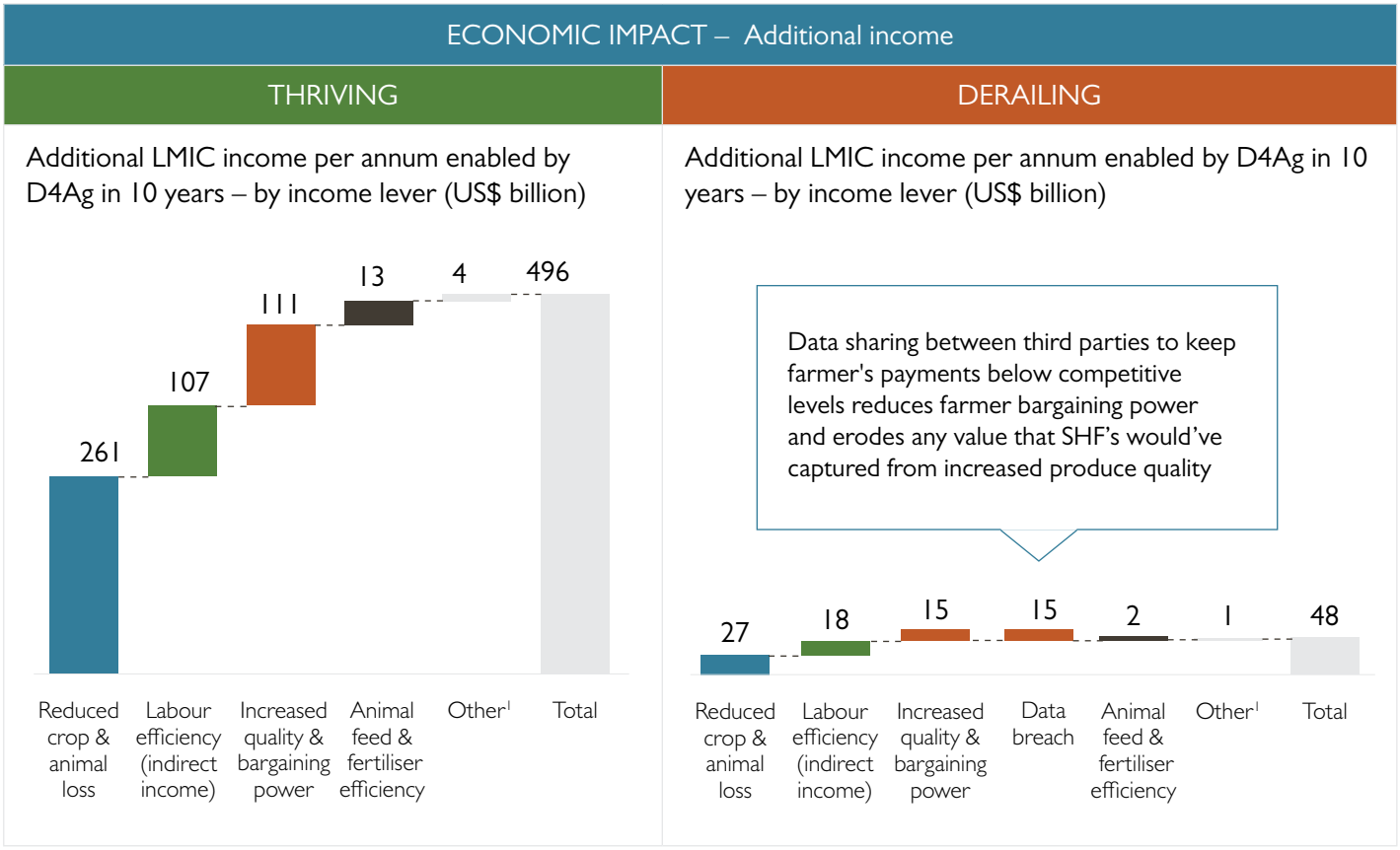
2. **Labor efficiency (indirect income):** D4Ag tools can save a significant amount of on-farm labor through and free up time for farmers to focus efforts elsewhere such as pursue additional work on-farm or in other industries. (Examples of enabling tools: precision agriculture advisory, smart irrigation, farm-machinery and equipment access, and digital marketplaces for inputs and outputs.)

3. **Increased quality and bargaining power:** D4Ag tools help disseminate knowledge, practices and help farmers access tools which can increase the quality of their produce. This coupled with greater bargaining power through access to a larger pool of off-takers and greater transparency on pricing, can greatly increase the prices received by farmers. (Examples of enabling tools: precision agriculture advisory, farmer information service, and digital marketplaces for outputs.)

4. **Animal feed and fertilizer efficiency:** For many farmers, fertilizer and pesticide application is ineffectively applied leading to large amounts of waste. Precision agriculture can allow for more targeted application at the right time, leading to input cost savings on inputs. Similarly for livestock, feed can be more efficiently used. (Examples of enabling tools: precision agriculture advisory, farmer information service, and digital marketplaces for outputs.)

5. **Other—carbon credits:** With access to climate marketplaces, farmers can be rewarded for certain climate-positive practices such as adopting agroforestry, cover cropping or conservation tillage techniques that increase carbon sequestration. (Examples of enabling tools: climate marketplaces and farmer information service.)

6. **Other—farm equipment maintenance savings: D4Ag** tools could predict when maintenance is required or monitor for issues (e.g., water leaks), allowing for farmers to address problems before they escalate into costly breakdowns (Examples of enabling tools: farmer information service, Farm Management Software, and IoT sensors.)



1. Other includes additional income from farmers earning carbon credits as a result of regenerative agroforestry & soil practices, and savings from farm machinery maintenance Note: There are likely to be other additional levers that have not been taken into consideration in this analysis Source: USDA ERS International Agricultural Productivity indices, Beanstalk analysis

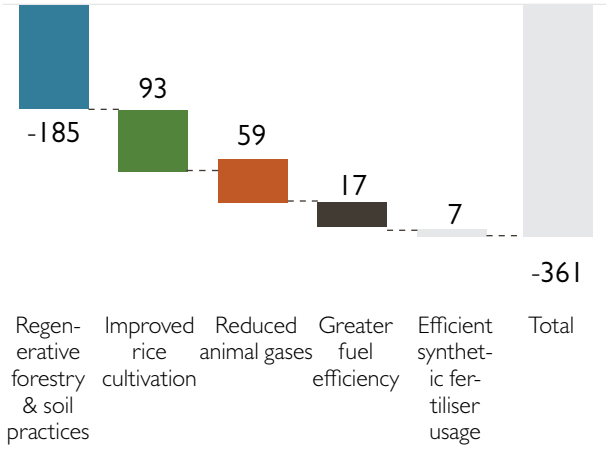
Figure 56. 10-Year outlook on Economic Impact enabled by D4Ag tools across LMICs

By the end of the next decade, of the US$496 billion additional income per annum that is enabled by D4Ag in the "thriving" scenario, it is estimated that reducing the yield gap and losses in livestock will contribute more than half (US$261 billion). The second and third significant contributors are unlocked human capital from labor efficiency gains, and an increase in selling prices of crops, livestock and aquaculture due to farmers leveraging D4Ag tools to produce higher quality products and gaining more bargaining power given greater market access and price transparency. Although climate marketplaces offer additional income opportunities and could add US$3 billion to the pockets of farmers across LMICs, the market will still be incredibly nascent (at estimated 10% penetration), and only contribute a small proportion of the total additional income increase by the end of the decade.

In the "derailing" scenario, we anticipate a much lower penetration of D4Ag tools, particularly in nascent and emergent countries where there will be lower investment and availability of solutions. This coupled with a much lower magnitude of impact for those who do uptake solutions–based on an assumption of lesser farm-facing support in sustaining effective D4Ag-enabled practice-change,–hampers value-generation down to only US$48 billion. Furthermore, adverse scenarios may unfold such as data breaches and exploitation of farmer data by third party companies, eroding away any potential value that farmers would have otherwise generated from increased prices (through higher quality produce and more bargaining power).

THRIVING

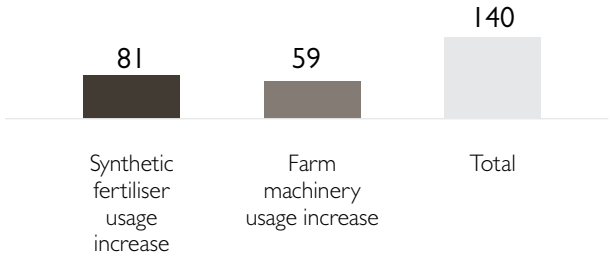
D4Ag-enabled farm-gate GHG reduction per annum in 10 years (CO2eq Megatons)



Applicable GHG (CO2eq Megatons)	491	1,882	111	265	4,188[1]
% reduction vs. baseline	-19%	-3%	-15%	-3%	-9%

DERAILING

D4Ag-enabled farm-gate GHG increase per annum in 10 years (CO2eq Megatons)



Applicable GHG (CO2eq Megatons)	265	111	4,188[1]
% reduction vs. baseline	+31%	+53%	+3%

1. Total farm-gate emissions in 2020 were 4,188 Megatons. Source: FAOSTAT domain Emissions Totals (last updated 22 May 2023), Beanstalk analysis

Figure 57. 10-Year Outlook on Environmental Impact enabled by D4Ag tools across LMICs

For environmental impact, we have identified five key areas of GHG emission reduction enabled by D4Ag tools.

1. **Regenerative forestry and soil practices**: Climate marketplaces provide financial incentives for farmers to adopt regenerative forestry and soil practices and earn an additional stream of income from selling carbon credits. By regenerative approaches, practices such as agroforestry and reducing tillage help sequester vast amounts of carbon in the soil. (Examples of enabling tools: climate marketplaces, precision agriculture advisory, and smart irrigation.)

2. **Improved rice cultivation**: Every year, rice cultivation is a significant emitter of methane gas, in particular when rice paddies are flooded with water during the growth phase. D4Ag can help enable purchase of climate-smart rice seeds, digital sensors to aid alternate wetting and drying techniques, water management systems, and access to information on best climate-practices. (Examples of enabling tools: precision agriculture advisory, farmer information service, water management systems, and digital marketplace for inputs.)

3. **Reduced methane emissions from ruminants**: Enteric fermentation refers to the digestive process of ruminant animals such as cattle, sheep and goats which is a major source of methane pollution. Through greater understanding of methane

Source: Feed the Future Flickr, Photo Credit: Mulugeta Ayene/WLE

production enabled by D4Ag, farmers can reduce methane gases through shifting diets to a low-emission one (e.g., seaweed additives, or increasing dietary oils), and improving animal productivity via sensor technologies that feed consumption. (Examples of enabling tools: precision agriculture advisory, farmer information service, feed efficiency, and digital marketplaces for feed additives that reduce methane.)

4. **Greater fuel efficiency**: Farm equipment such as tractors and harvesters rely on fuel for operation. As D4Ag enables more precise farming, and software systems and sensors can better monitor and predict equipment maintenance needs, the usage of farm equipment and subsequently fuel is also optimized. (Examples of enabling tools: precision agriculture advisory, farmer information service, and equipment and machinery management systems.)

5. **Efficient synthetic fertilizer usage**: D4Ag can enable precise application of fertilizer by using GPS or sensor data to optimize nutrient distribution across soil with different requirements. By optimizing synthetic fertilizer usage, farmers can greatly reduce overapplication and subsequently the release of nitrous oxide emissions. (Examples of enabling tools: precision agriculture advisory and farmer information service.)

Smallholder farmers in LMICs have significant challenges concerning underutilization of fertilizer and a notable absence of on-farm mechanization. D4Ag can solve availability and financial limitations that prevent farmers from accessing these inputs and assets (e.g., through

new business models involving farm-equipment leasing or online information services), however from a "derailing" perspective, this may exacerbate current environmental issues if caused by:

1. **Increased usage of synthetic fertilizer:** Increased access to digital finance and marketplaces may cause farmers to purchase additional inputs that they are already using (i.e., synthetic fertilizers) rather than change to alternative inputs or practices that have a lower environmental footprint.

2. **Increased usage of farm machinery:** A proliferation of fuel-based farm equipment such as tractors and harvesters will lead to increased GHG emissions released.

There is potential for current farm-gate emissions to be reduced by 9% (361 Megatonnes of CO2eq) in the "thriving" scenario, with adoption of regenerative forestry and soil practices being the largest impact lever. In the "derailing" scenario, current emissions would only worsen with an additional 3% (140 Megatonnes of CO2eq) emitted into the atmosphere. The reality may be much worse as volume increases have not been taken into account in the model, which would require additional inputs and farm equipment to cultivate.

Source: Feed the Future Flickr. Photo Credit: Daljit Singh

FOR DIFFERENT STAKEHOLDERS

Recommendations to strengthen the productivity and impact of D4Ag ecosystems in LMICs—particularly from reports tied to donor projects—are not in short supply. However, there are a few reasons we believe the recommendations that are to follow in this section should still hold some value for stakeholders aiming to amplify the impact of D4Ag solutions across the globe:

1. **Global reach:** Several studies and strategies have been conducted/formulated at solution, market, or even regional level. Few (if any) have aimed rather to draw out similarities, challenges, and opportunities at global (LMIC) scale.

2. **Time series:** In the coming five years after the landmark "The Digitalisation of African Agriculture Report 2018–2019," we are again at a crossroads of D4Ag. This year marks at least a decade with relatively rapid and continuous growth for the D4Ag sector—insights and lessons learned are increasingly making themselves known, and in some cases bearing fruit as observed impact.

3. **Breadth of engagement:** We have been fortunate enough to deep dive and learn from more than 250 individuals directly—whether through one-on-one interviews or in regional workshops. Further, we have had several hundred responses to multiple surveys, providing a new level of quantitative insight on core questions of adoption, profitability, ecosystem trajectories, challenges observed, and opportunities in focus.

4. **Challenge, stakeholder, and context specificity:** We have aimed to gear the recommendations with particular mind to individual stakeholders (i.e., YOU)—their challenges, contexts, capabilities, and operating environments (i.e., level of ecosystem maturity).

5. **Starting point (on others' shoulders):** These recommendations and this study have not been about recreating the wheel, but about validating and extending learnings from existing research.

Earlier, we explored the dichotomy of possible futures for D4Ag: the perils of "derailing" and the promise of a "thriving" ecosystem. The bifurcation between these contrasting prospects underscores the gravity of our collective choices and strategies on the future of the D4Ag ecosystem, as well as the stakeholders across it. It is with this backdrop that we present the ensuing recommendations, mindful of the unique and varying roles that different stakeholders play across the D4Ag ecosystem. What follows, though, are not just recommendations but actionable and referenceable interventions. Their aim is to help ensure that we edge closer to a resilient, inclusive and "thriving" D4Ag ecosystem across LMICs.

1. Support the formulation and implementation of inclusive, climate-smart policies for D4Ag: Focus on creating robust policy frameworks that promote climate-smart digital agriculture, taking into account industry standards, regional alignment, and infrastructure development.

2. Invest in capacity building and knowledge sharing across the D4Ag ecosystem: Emphasize training for a digitally native agricultural workforce, close knowledge gaps on D4Ag's impact across diverse sectors, and promote digital literacy and empowerment especially among marginalized groups.

3. Sustain, boost, and diversify funding and investment for D4Ag: Drive more adaptive and outcome-oriented funding structures, identify and address principal funding gaps, and ensure investors incorporate impact into core investment processes and structures.

4. Accelerate the development of infrastructure to support D4Ag: Expand funding pathways for essential infrastructure, whether physical (i.e., rural telecommunication, warehousing, cold storage, and environmental monitoring technologies) or digital (i.e., data warehousing, farmer / land registries, environmental and demographic data layers, etc.).

5. Foster collaboration, data, and resource sharing across the D4Ag ecosystem: Encourage multi-stakeholder engagements, comprehensive and accessible data on D4Ag innovation in LMICs, and strategic partnerships (both within and across the regions) to collectively address common challenges and visions for D4Ag and boost funding to the sector.

6. Hone in on D4Ag end-user needs through focused and inclusive engagement: Support and encourage innovators to differentiate with clear value propositions, embed inclusivity, and prioritize deep user engagement. Support and encourage primary producers to experiment, feedback, and advocate for capacity building.

There are critical actions that each stakeholder can take to contribute to a more productive, viable, and positively impactful D4Ag ecosystem across LMICs as per the recommendations above. Below are our principal recommendations for several principal players which we believe to be relevant across LMIC regions.

Source: Feed the Future Flickr. Photo credit: Maria Luisa Ramirez Cruz

Recommendation	Category
Governments	
1. Lay fit-for-purpose policy and regulatory foundations for inclusive, climate-smart D4Ag ecosystem (i.e., targets, roadmap, focal points, governance, models of support, priority initiatives) **1.1.** Develop a comprehensive roadmap with clear targets and milestones for the adoption and scaling of viable, inclusive, and impactful digital agriculture innovation. (Example: Colombia's Viva Digital (2010-14), and successor Viva Digital para la Gente (2014-18)) **1.2.** Establish dedicated departments or focal points within the government to oversee and coordinate digital agriculture strategies and initiatives. (Example: Singapore's Smart Nation Digital Government Group (SNDGG)) **1.3.** Consider and accommodate for leveraging of digital agriculture tools in design of carbon credit programs and other market-based mechanisms to manage environmental externalities—for example, in allowable emissions reduction methodologies and allowable means of measurement. (Example: Open Collaboration for Digitising Impact, facilitated by Gold Standard and supported by Google.Org, with working group contributions from various public, private, and social sector partners) **1.4.** Invest in gender-transformative policies and approaches that address the imbalanced power dynamics in government to ensure gender parity within departments and enable lived experience knowledge in legislation and policy frameworks pertaining to D4Ag. (Example: Coordinated and complementary institution of Gender Machinery, Gender Mainstreaming Policy, and Agriculture Gender Strategy over last 15+ years in Rwanda)	
2. Further invest in development and dissemination of "data as a common good" for D4Ag. **2.1.** Provide guidance, in-kind support, and incentives to agribusiness and value chain actors to adopt and/or contribute to emerging data sharing and exchange standards and open source data initiatives which improve viability and user-centricity of D4Ag solutions. **2.2.** Support the development of dedicated data cooperatives and consortiums (i.e., specific to service of respective "farmer profiles") across agricultural value chains, and offer incentives for active and outcome-oriented contribution (i.e., tax reduction, aggregated insights, product / solution discounts and subsidies, promotion) by farmers, agribusinesses, and technology providers. **2.3.** Develop solid supporting regulations, such as data privacy laws, data localization norms, and data protection regulations for secure, transparent, and accountable data collection and storage, ensuring that that farmers can access and use their own data.	
3. Pursue regional and intergovernmental alignment to better support / leverage D4Ag. **3.1.** Develop knowledge-sharing platforms and ongoing dialogues with peer countries at similar levels of D4Ag ecosystem maturity, with similar concentrations of distinct farmer profiles, and/or highly comparable industry challenge statements to exchange experiences, best practices, and even D4Ag solutions. **3.2.** Consider D4Ag and digital / data infrastructure in bilateral and multilateral trade negotiations, supporting pathways to enable adoption and diffusion of critical infrastructure and equipment for D4Ag solution development and expansion.	
4. Strengthen a "digitally native" agricultural workforce (including students, agribusiness employees, university staff, extension agents, co-op/farmer group leaders). **4.1.** Invest in, and design for, UX/UI improvement in national agricultural information systems and databases to improve navigability, usefulness, and use of publicly available data. **4.2.** Support the development and accreditation of D4Ag-centered vocational training, short-courses, and curricula for secondary and tertiary education—both in "ag" and "tech" programs.	

Recommendation	Category
5. Double down on investment in digital inclusion and empowerment—particularly for women and marginalized sub-populations. **5.1.** Facilitate the creation of community-based digital hubs or telecenters that serve as safe spaces for women and marginalized groups to access digital agriculture resources, receive training, and engage in peer-to-peer learning and collaboration. **5.2.** Develop omni-channel awareness campaigns and user-friendly educational materials in local languages to enhance digital literacy among women, youth, and marginalized communities, empowering them to leverage digital agriculture tools for improved productivity and livelihoods. **5.3.** Foster partnerships with women's organizations, community-based groups, and NGOs to design and deliver gender-transformative training initiatives, mentorship programs, and awareness campaigns on digital agriculture.	
6. Expand funding for physical infrastructure, particularly where enabling/complementing D4Ag directly (mobile devices and connectivity; warehousing and cold storage; sensor networks; emissions measurement tech; etc.). **6.1.** Strategically expand funding for building and maintenance of telecommunication infrastructure in remote and rural areas—not only cell towers, transmission lines, and fiber-optic cables, but also potentially fit-for-purpose technologies like TV White Space (TVWS), mesh networking, and solar-powered base stations. (Example: Microsoft's TV White Space Pilots in Ghana) **6.2.** Advance policy to stimulate private sector investment in D4Ag infrastructure—i.e., performance-based subsidies, tax incentives and exemptions, public-private partnerships (PPPs), or fit-for-purpose levies directed to rural connectivity projects. (Example: Pakistan's Universal Service Fund) **6.3.** Further develop and upgrade core agricultural value chain infrastructure—such as warehousing, cold chain facilities, and efficient transport networks—with digital integration in mind. **6.4.** Invest in scaling measurement and monitoring technologies for GHG emissions and other environmental impacts to remote and rural areas, with focus on building an evidence base for policies, solution providers, and farmers themselves whilst accelerating the development curve of fit-for-purpose (i.e., climate-smart) D4Ag solutions.	
Donors	
1. Consider longer-term, adaptive, and outcome-oriented programs for D4Ag support (i.e., enabling deeper co-design and focus on "harder-to-reach" sub-populations). **1.1.** For funding targeted toward deployment of D4Ag solutions, consider structuring funding, support, and project stages/lifetime on milestone achievements (i.e., "unlocks"), rather than fixed timelines.	
2. Further invest in closing the knowledge gap on differentiated D4Ag penetration and impact (i.e., across value chains, use cases and solutions, sub-populations, indicators). **2.1.** Ramp up investment in establishment of independent research and industry-wide benchmarks with respect to impact and effectiveness of various digital agriculture solutions across different value chains, sub-populations, and regions.	
3. Extend catalytic funding where principal funding gaps exist for D4Ag innovators and adopters. **3.1.** Conduct comprehensive, place-based assessments of local funding gaps across different investment classes and sizes to optimize the targeting of donor-financed and -supported investment programs, and to guide private investors in gap-filling capital allocation. **3.2.** Provide co-funding to catalyze and co-invest beside locally oriented angel networks for investment in D4Ag and other industrial digital solutions. **3.3.** Develop evaluative frameworks, guidance, and co-investment to support financial institutions to extend fit-for-purpose working capital and short-term debt (i.e., via revolving funds, social impact bonds, venture debt, and/or credit guarantees	

Recommendation	Category
4. Support data sharing and development of common taxonomies, standards, and impact indicators to be leveraged across the D4Ag ecosystem (particularly startups, investors, and governments). **4.1.** Invest in tools or databases that promote transparency of data and insights for the D4Ag sector, at the innovator and market level. **4.2.** Develop and activate a (permanent, mission-based) working groups—comprising donors, government representatives, corporate agribusinesses, and investors—to define and standardize sector-level learning agendas, common taxonomies, standards, and key performance indicators for progress from D4Ag. **4.3.** Co-invest in "control rooms" to support government agencies to better monitor and strategically improve on commonly defined "impact indicators."	
5. Generate and share knowledge regarding "responsible deployment" of emerging technologies and business models in D4Ag (i.e., avoiding pitfalls and adverse impacts). **5.1.** Support the establishment and appropriate structuring of a global monitoring and learning platform, whereby innovators, investors, and other D4Ag stakeholders can stay informed on latest advancements, challenges, and successes in deploying and using D4Ag in LMICs. **5.2.** Fund the development and regular updating of living guides (i.e., as wikis) on responsible deployment of D4Ag solutions with targeted users across different sub-populations (i.e., ethnic minorities, people living with disabilities), respectively. **5.3.** Conduct regular "post-mortems" on D4Ag innovators that close down operations, as well as deployments/initiatives recognized for inefficacy/adverse outcomes, and broadcast across D4Ag networks. **5.4.** Organize/support establishment of "learning from failure" events for D4Ag innovators—inspire by the "F ailFest" format, to create a safe space for entrepreneurs, investors, and stakeholders across the D4Ag ecosystem to discuss and learn from pitfalls and adverse impacts encountered and/or generated.	
Corporate Agribusinesses	
1. Pursue cross-industry collaboration to elaborate shared challenges and vision for D4Ag **1.1.** Build/join pre-competitive consortia to address common industry challenges through shared challenge definition, pooled resources, and collective knowledge in a collaborative environment. (Example: GRAFT Challenge) **1.2.** Participate in multi-stakeholder platforms—industry forums, conferences, or working groups, for example—focused on D4Ag challenges and solutions. (Example: Grow Asia)	
2. Explore opportunities to strategically "share" datasets to improve targeting and impact of D4Ag. **2.1.** Take steps to prepare for responsible, secure, and productive data sharing for mutual benefit with commercial and social partners: strengthen your organization's data governance frameworks, data collection/management, and security/privacy processes; invest in training programs to upskill employees in data literacy and management; and create templates and standard processes for data sharing agreements with third parties. **2.2.** Assess your own organization's data needs and goals to identify areas where data sharing can enhance decision-making, efficiency, reach, or sustainability of your operations, and where there are potential partners who possess complementary datasets and are likely to draw mutual benefit through collaboration. **2.3.** Consider participation in industry-specific data collaboration platforms that facilitate secure and standardized data sharing across agribusinesses and their partners. (Example: Global Open Data for Agriculture and Nutrition)	

Recommendation	Category
3. Support employees to better understand, use, and promote inclusive and impactful D4Ag **3.1.** Organize internal innovation challenges or hackathons focused on digital solutions for persistent challenges across your company's supply chain, where locally present D4Ag solution providers and ecosystem enablers can serve as collaborators and/or coaches. **3.2.** Sponsor employees' investment in digital agriculture learning—whether through attending conferences, continuing education, or even secondment with D4Ag solution providers. **3.3.** Establish a cross-functional "Digital Ambassador Program" to drive digital transformation and knowledge dissemination across your business—selecting fit-for-purpose individuals with passion for digital solutions, strong communication skills, and enthusiasm to lead and educate others; training and empowering them as champions for digital initiatives across the organization; facilitating regular knowledge-sharing and community-building initiatives to educate and inspire colleagues.	
4. Invest in board quotas and gender & social inclusion training of board members to ensure diversity and deep understanding of digital inclusion barriers and challenges and the importance of digital inclusion investment.	
Enabling Service Providers	
1. Proactively and strategically engage D4Ag solution providers to drive shared value partnerships. **1.1.** Establish a dedicated team or unit within the organization to actively seek, evaluate, and engage with relevant and complementary D4Ag solution providers.	
2. Generate and share intelligence to improve targeting and impact of D4Ag. **2.1.** Share anonymized and aggregated data with D4Ag solution providers to support the development of appropriately trained and tailored products and services.	
3. Advocate for and invest in D4Ag-friendly regulation, standards, and infrastructure. **3.1.** Collaborate through/with industry associations and other stakeholders to develop and promote industry-wide standards for D4Ag (as they relate to your line of business, in particular) to facilitate broader interoperability, data sharing, and transparency across the D4Ag landscape.	
4. Train and support supply chain partners and customers in digital/D4Ag literacy and capability building. **4.1.** Foster relationships between established corporate agribusinesses (i.e., input suppliers, off-takers) and D4Ag solution providers to generate additional value from your own products/services. **4.2.** Introduce training programs, workshops, and on-call support to supply chain partners—including producers themselves—to enhance digital literacy and build confidence with digital tools.	
Investors	
1. Integrate "impact" into core processes (i.e., diligence) and business structure (i.e., returns), including vigilance to "greenwashing" and avoiding future risk to credibility and viability. **1.1.** Adopt impact targets, measurement practices, and focus indicators in alignment with emerging "industry standards" (i.e., GIIN's impact performance benchmarks for agriculture) and peer "action groups" (i.e., ClimateShot Investor Coalitions' action group on "evidence-based tools"). **1.2.** Commit to—and commit resources to—reputable third-party impact assessment professionals / firms to observe and report on social and/or environmental impact with regularity and over mid-to-long term (i.e., annually for fund lifetime). **1.3.** Work with limited partners and other suppliers of funds to structure investment vehicles designed to reward (i.e., modulating "carry" for venture funds) positive social and/or environmental impact.	

Recommendation	Category
2. Promote broader representation within the investment ecosystem. **2.1.** Commit to improving diversity, equity, and inclusion through investment team structure / recruiting, operations, and disclosure according to established industry benchmarks and guidelines. (Example: Asset Owner Diversity Charter) **2.2.** Develop fit-for-purpose "attraction strategies" for women and other underrepresented social groups, including tailored actions at levels of job advertisement (i.e., located where target groups will notice them, using inclusive language, offering a contact from within the sub-population), policies (i.e., benefits and exceptions perceptive to sub-populations' needs), and general network-building (i.e., engaging with sub-population-specific clubs, institutions, and communities; sponsoring public competitions and awards ceremonies). **2.3.** Offer "apprenticeship" and/or other leadership programs directing support, mentorship, and resources to employees belonging to target sub-populations to maximize likelihood of retention and progression to leadership roles.	
3. Explore opportunities to invest in and/or strengthen development of D4Ag "enablers." **3.1.** Publicly organize and advocate for large-scale (i.e., public) investment in D4Ag enabling infrastructure. **3.2.** Organize "innovation challenges" and launch RFPs with focus on supporting further development and improvement of technical D4Ag "enablers" (i.e., middleware, databases, etc.)—i.e., through "winning" opportunity to trial / co-develop solutions with portfolio companies. **3.3.** Fund other funds deploying capital to D4Ag "enablers" with different investment hypotheses, required knowledge/networks, and return structures (i.e., middleware, physical inputs, deeptech). **3.4.** Consider co-funding social and behavioral change programs and initiatives improving ability to engage with and benefit from D4Ag solutions.	
4. Consider diversification of investment models to tap into different use cases/geographies. **4.1.** Consider "downscaling" expected/target investment rounds in nascent and emerging D4Ag ecosystems. **4.2.** Deploy alternative (especially debt-based) investment structures for non-SaaS/FinTech D4Ag solutions, to accommodate for profit-generating businesses with different scale/growth patterns. **4.3.** Partner with and capitalize local angel investors and networks to leverage local knowledge and expertise in new markets, close early stage investment gaps, and expand base of capable (co-) investors in nascent and emerging markets. **4.4.** Explore setting up fit-for-purpose sidecar funds targeting specific D4Ag solution areas or geographies. **4.5.** Consider investment in discrete, catalytic partnership opportunities (within or outside portfolio) to support scale and exposure for D4Ag solutions and the category more broadly.	
5. Develop and capitalize AgTech-specific incubators and accelerators. **5.1.** Consider starting with "hackathons," "short courses," and "case competitions" focused on agricultural development challenges to attract young talent, researchers, and entrepreneurs with innovative solutions to address pressing agricultural challenges. (Example: xxx) **5.2.** Collaborate with university programs in agriculture and agribusiness to establish dedicated AgTech incubator programs to support and nurture student, graduate, and faculty-led enterprises, levering existing center of university resources, expertise, research, and facilities. (Example: Establishment of India's first food and agribusiness accelerator in 2015 by IIM Ahmedabad, in partnership with a-IDEA) **5.3.** Create specialized startup support programs within AgTech incubators and accelerators focused on fostering diversity and social impact—i.e., intentionally supporting underrepresented groups such as women, ethnic minorities, and people with disabilities in their entrepreneurial journeys. (Example: Google for Startups Black Founders Fund [in Africa])	
Innovators	

Recommendation	Category
1. Differentiate in a crowded and fatigued field through clarity of value prop. **1.1.** Develop, target, and engage with detailed user personas based on shared behaviors, challenges, and preferences; be careful to consider intersecting identities (i.e., elderly x women x rural) and implications for users' pain points and goals. **1.2.** Be realistic, credible, and data-driven in claims of impact so as not to erode trust (in yours and others' D4Ag solutions) and to draw optimal end-user base.	
2. Embed gender and social inclusion into your organizational strategy. **2.1.** Make time to discuss gender and social equity in Board and Executive meetings. **2.2.** Add board quotas for women participation. **2.3.** Establish holistic gender & social inclusion strategies, with clear objectives and targets defined by your own data. **2.4.** Be specific—understand that "social equity" encompasses a broader range of sub-populations with intersecting identities, challenges, and ambitions with respect to D4Ag; do not tackle all at once.	
3. Open new paths to market through differentiated intermediaries and delivery channels—particularly those who have already built trusted and credible relationships. **3.1.** Create a detailed map of trusted advisors, service providers, and influencers to your target end users who play a role in decision-making processes most relevant to your solutions. **3.2.** Engage in dialogue, collaboratively co-create with, and offer training and support to trusted intermediaries to better develop and deploy D4Ag solutions. **3.3.** Rather than building channel partnerships from scratch, look to leverage established distribution channels, such as through "shared channel infrastructure" with other (potentially complementary) D4Ag solution providers.	
4. Generate virtuous feedback loops through deeper user engagement and impact measurement. **4.1.** Provide incentives—i.e., discounts, rewards, exclusive access to new features, promotion, and/or public / private recognition—for constructive user feedback. **4.2.** Implement and analyze data from multiple channels of user feedback—in-app feedback forms, email surveys, customer support chatbots, in-person interviews—and integrate it into product development workflows: monitor, respond to, and address suggestions. **4.3.** Audit and revise data architecture and collection/processing pathways to support sex-disaggregation (and other user information, as appropriate) for data across the product life cycle—not just at registration. **4.4.** Guarantee that feedback loops are inclusive to ensure marginalized voices are accounted for.	
Primary Producers and Associations	
1. Experiment, feedback, and iterate in partnership with D4Ag solution providers. **1.1.** Provide timely and constructive feedback to solution providers—whether directly, through digital reviews, or indirectly—regarding the usability, effectiveness, and relevance of the D4Ag solutions to facilitate their refinement and adaptation to your and your peers' needs	
2. Embrace and advocate for capacity building from extension agencies, research and education institutions, and D4Ag solution providers themselves. **2.1.** Establish a "farmer field school" with dedicated sessions on D4Ag where extension agents, D4Ag solution providers, university personnel, or others are proactively invited to share and spread knowledge. (Example: FAO's Global FFS Dgroup)	
3. Seek out and foster partnerships with agribusinesses and value chain partners to create market incentive for D4Ag solution adoption. **3.1.** Send representatives to industry events and forums on D4Ag and agricultural innovation more generally where value chain partners—including D4Ag solution providers—are more often present **3.2.** Engage with local governments and policymakers to advocate for policies and incentives to promote broader engagement of (smallholder) farmers—particularly, underrepresented sub-populations—by agribusinesses.	

Recommendation	Category
4. Organize and cooperate based on shared challenges. **4.1.** Establish or join regional networks to facilitate knowledge sharing, peer learning, joint investment, and collective testing/piloting of D4Ag solutions oriented toward local challenges. **4.2.** Advocate for investment in local infrastructure, digital foundations, and data instrumental to viability of D4Ag solutions in your locale.	
5. Value your data—share where there is shared value. **5.1.** Ask for, review, and consult with third-party support (i.e., extension agents, legal professionals, cooperative / association leaders, data protection authorities) regarding data management and use policies for respective D4Ag solutions, particularly with respect to ownership and control, privacy and security, transparency and consent, portability, and right-to-access. **5.2.** Advocate for, develop and adopt data governance frameworks and codes of conduct specific to D4Ag, with focus on ensuring that producers' rights, data privacy, and fair data sharing practices are protected and promoted, and providing a mechanism whereby D4Ag solution providers can have their data terms and policies assessed for compliance and certification. (Example: Australian Farm Data Code).	

Table 19. Principal Recommendations for D4Ag Stakeholder Groups.

Appendices

APPENDIX 1. CONTEXT AND METHODOLOGY

The focus of this study was twofold: first, to assess the current state and future trajectory of D4Ag across four crucial LMIC regions worldwide; and second, to put forward a set of actionable recommendations for ecosystem stakeholders. These recommendations aim to foster the emergence of a commercially viable, climate-smart, and socially inclusive future for D4Ag.

Our methodology employed a comprehensive mix of primary and secondary research. We conducted interviews with over 190 thought leaders and practitioners from more than 50 countries, held six workshops involving approximately 60 D4Ag ecosystem stakeholders, and deployed a survey which received over 80 responses from D4Ag innovators. Additionally, we conducted an extensive literature review of over 200 resources and built a database of more than 1,300 D4Ag solutions, classifying various critical factors.

We aim to build on the valuable work of many others in this report, providing a foundation for open dialogue and offering sensible guidance for future action. We recognize the current "data-poor" environment and are keen to contribute toward changing this reality.

In this report, we took on several key tasks. We (i) attempt to (re)define D4Ag and establish a common language for the sector, its ecosystem, and its intersectional themes; (ii) reflect on the current state of the sector, considering its growth in the past five years and the challenges and opportunities it faces in the next five-plus; (iii) provide in-depth analysis on cross-cutting themes for D4Ag including "impact," "climate-smart D4Ag," "funding and investment," and "gender equity and social inclusion" (GESI); (iv) propose alternative "future outlooks" for LMIC agricultural systems influenced by D4Ag ecosystem advancement; and (v) offer perspectives on the respective actions that different actors should prioritize to advance these target outcomes without compromising—but rather, co-achieving—public and private interests alike.

Reach and Adoption Detailed Methodology

For the purposes of estimating the adoption and projecting future outlooks in this report, we focus exclusively on low- and middle-income countries. High-income countries, while often "suppliers" of D4Ag innovation, are not included in our assessment from a reach and adoption perspective.

Region	Leaders	Emergent	Nascent
Latin America and the Caribbean	Brazil	Argentina Colombia Mexico	Belize Bolivia Costa Rica Cuba Dominican Republic Ecuador El Salvador Guatemala Haiti Honduras Jamaica Nicaragua Paraguay Peru Suriname Venezuela
Sub-Saharan Africa	Kenya Nigeria	Ethiopia Ghana Rwanda Senegal South Africa Tanzania Uganda Zambia Zimbabwe	Angola Benin Botswana Burkina Faso Burundi Cameroon Central African Republic Chad Democratic Republic of the Congo Djibouti Equatorial Guinea Eritrea Gabon Gambia Guinea Guinea Bissau Ivory Coast Lesotho Liberia Madagascar Malawi Mali Mauritania Mozambique Namibia Niger Republic of Congo Sierra Leone Somaliland South Sudan Swaziland Togo
South Asia	India	Bangladesh Pakistan Sri Lanka	Afghanistan Nepal

Region	Leaders	Emergent	Nascent
Southeast Asia	NA	Indonesia Malaysia Thailand Vietnam	Cambodia Timor-Leste Laos Myanmar Philippines

Table 20. Countries Classification according to D4Ag Advancement Level

Regarding current adoption rates, we conducted searches of academic literature through academic research databases and consulted publicly available knowledge resources. Given the breadth of this study both geographically and technically across a wide spectrum of D4Ag solutions, there was limited data that provided a complete view across the globe. As such, we have made estimates on current rates on adoption as the baseline, by leveraging available country data and applying the Digital Adoption Index7 with an adjustment factor. Estimates of current levels of adoption is at 8% for D4Ag accounting for duplication. Farmers who are actively using D4Ag tools are likely to use multiple tools, and it is highly probable that there is greater duplication of D4Ag usage than previously assuming a large portion of growth in users is from already active users adopting new tools rather than completely "new" adopters.

To forecast what adoption would look like in the next 10 years, we first used the adoption curves of Individuals using the Internet (% of population)8 from World Bank and applied a lag factor of 10 years for Leaders, 12 years for emergent markets, and 15 years for nascent markets which were adjusted to yield a plausible outcome in 2033. The rationale here, as an example, is that the current state of D4Ag in leader markets is 10 years behind internet penetration, and thus the adoption curve growth rate would closely follow that of how internet penetration was 10 years ago. Adjustment factors were applied to each region and by maturity level for both the derailing scenario and thriving scenario.

The table below summarizes the adoption forecast of active users by year.

Region	Maturity	THRIVING SCENARIO – % farmers who are active users of specialized, for purpose D4Ag tools										
		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Latin America and the Caribbean	Leaders	40%	43%	45%	48%	51%	53%	59%	62%	65%	71%	71%
	Emergent	20%	26%	30%	33%	35%	38%	40%	42%	44%	46%	47%
	Nascent	6%	6%	7%	7%	7%	8%	8%	10%	12%	13%	14%
Sub-Saharan Africa	Leaders	13%	15%	18%	23%	24%	24%	25%	28%	32%	36%	41%
	Emergent	6%	6%	8%	13%	16%	20%	26%	27%	27%	28%	28%
	Nascent	3%	3%	4%	4%	5%	6%	9%	13%	18%	18%	18%
Southeast Asia	Leaders	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Emergent	8%	11%	13%	15%	15%	17%	22%	25%	31%	37%	43%
	Nascent	3%	4%	4%	4%	5%	5%	6%	7%	8%	8%	12%
South Asia	Leaders	13%	14%	15%	17%	18%	20%	23%	25%	37%	54%	57%
	Emergent	5%	6%	7%	8%	9%	15%	17%	22%	23%	27%	31%
	Nascent	4%	3%	3%	6%	7%	8%	9%	9%	11%	13%	16%
	TOTAL	8%	10%	11%	13%	14%	17%	20%	22%	28%	35%	38%

Economic Lever	Maturity	THRIVING SCENARIO – no. of farmers who are active users of specialized, for purpose D4Ag tools (millions)											
		No. of Agri workers	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Latin America and the Caribbean	Leaders	7.9	3.2	3.4	3.5	3.8	4.1	4.2	4.7	4.9	55.1	5.7	5.6
	Emergent	11.1	2.2	2.9	3.3	3.6	3.9	4.2	4.4	4.6	4.9	5.1	55.2
	Nascent	18.8	1.0	1.1	1.2	1.3	1.3	1.5	1.5	1.7	2.1	2.4	2.6
	TOTAL	37.8	6.4	7.4	8.1	8.7	9.3	10.0	10.7	11.3	12.1	13.1	13.4
Sub-Saharan Africa	Leaders	27.8	3.5	4.1	5.1	6.5	6.5	6.5	7.0	7.7	8.9	10.1	11.3
	Emergent	79.6	4.4	5.1	6.1	10.0	12.4	15.7	20.8	21.7	21.8	22.0	22.1
	Nascent	95.4	3.0	3.2	3.5	3.9	4.4	6.2	8.6	12.1	16.8	17.0	17.6
	TOTAL	202.8	10.9	12.5	14.6	20.4	23.3	28.5	36.3	41.4	47.5	49.1	51.0
Southeast Asia	Leaders	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Emergent	69.9	5.2	8.0	8.9	10.3	10.6	12.0	15.1	17.2	21.4	25.9	30.4
	Nascent	26.7	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.8	2.0	2.2	3.1
	TOTAL	96.7	6.2	9.0	9.9	11.5	11.9	13.5	16.7	19.0	23.4	28.0	33.6
South Asia	Leaders	186.6	23.3	25.7	28.5	31.3	34.5	38.2	42.2	46.5	68.4	100.5	107.3
	Emergent	52.8	2.7	3.1	3.6	4.0	5.0	8.2	8.7	11.5	12.4	14.2	16.3
	Nascent	13.4	0.5	0.4	0.4	0.8	0.9	1.1	1.2	1.3	1.5	1.7	2.2
	TOTAL	252.8	26.5	29.3	32.6	36.0	40.4	47.5	52.0	59.3	82.3	116.5	125.8
	TOTAL	590.1	50.0	58.1	65.2	76.6	84.9	99.3	115.8	131.0	165.3	206.7	223.8

Region	Maturity	DERAILING SCENARIO – % farmers who are active users of specialized, for purpose D4Ag tools										
		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Latin America and the Caribbean	Leaders	40%	41%	42%	44%	45%	46%	49%	50%	51%	54%	53%
	Emergent	20%	22%	23%	23%	24%	25%	25%	25%	26%	26%	26%
	Nascent	6%	6%	6%	7%	7%	7%	7%	8%	9%	10%	11%
Sub-Saharan Africa	Leaders	13%	13%	15%	16%	16%	16%	17%	17%	19%	20%	21%
	Emergent	6%	6%	7%	9%	10%	11%	13%	13%	13%	13%	13%
	Nascent	3%	3%	3%	3%	4%	4%	5%	5%	6%	6%	6%
Southeast Asia	Leaders	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Emergent	8%	9%	9%	10%	10%	10%	11%	12%	12%	13%	14%
	Nascent	3%	3%	4%	4%	4%	4%	4%	4%	4%	4%	5%
South Asia	Leaders	13%	13%	14%	14%	15%	15%	16%	17%	20%	23%	24%
	Emergent	5%	5%	6%	6%	7%	9%	10%	11%	12%	12%	13%
	Nascent	4%	4%	3%	4%	5%	5%	5%	5%	6%	6%	6%
	TOTAL	8%	9%	9%	10%	11%	11%	12%	13%	14%	16%	16%

Region	Maturity	DERAILING SCENARIO – no. of farmers who are active users of specialized, for purpose D4Ag tools (millions)											
		No. of Agri workers	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Latin America and the Caribbean	Leaders	7.9	3.2	3.3	3.4	3.5	3.6	3.7	3.9	4.0	4.1	4.3	4.2
	Emergent	11.1	2.2	2.4	2.5	2.6	2.7	2.7	2.8	2.8	2.8	2.9	2.9
	Nascent	18.8	1.0	1.1	1.2	1.2	1.2	1.3	1.4	1.5	1.7	1.8	1.9
	TOTAL	37.8	6.4	6.8	7.0	7.3	7.5	7.7	8.0	8.2	8.6	9.0	9.1
Sub-Saharan Africa	Leaders	27.8	3.5	3.7	4.1	4.5	4.5	4.5	4.7	4.9	5.2	5.4	5.7
	Emergent	79.6	4.4	4.8	5.2	6.9	7.7	8.8	10.2	10.4	10.4	10.5	10.5
	Nascent	95.4	3.0	3.1	3.1	3.3	3.4	3.9	4.4	5.0	5.6	5.6	5.7
	TOTAL	202.8	10.9	11.6	12.4	14.7	15.7	17.2	19.2	20.2	21.2	21.5	21.9
Southeast Asia	Leaders	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Emergent	69.9	5.2	6.2	6.4	6.7	6.8	7.1	7.7	8.1	8.7	9.3	9.9
	Nascent	26.7	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2
	TOTAL	96.7	6.2	7.1	7.3	7.7	7.8	8.1	8.8	9.1	9.8	10.4	11.1
South Asia	Leaders	186.6	23.3	24.3	25.3	26.3	27.4	28.6	29.8	31.0	36.8	43.8	44.9
	Emergent	52.8	2.7	2.9	3.1	3.3	3.7	4.9	5.1	5.9	6.1	6.5	7.0
	Nascent	13.4	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.9
	TOTAL	252.8	26.5	27.6	28.9	30.2	31.7	34.1	35.5	37.6	43.7	51.1	52.8
	TOTAL	590.1	50.0	53.1	55.8	59.9	62.7	67.2	71.5	75.2	83.3	92.0	94.9

Table 21. Adoption Forecast of Active Users by year.

Women Inclusion

Our team collected total reach information including the number of farmers registered and % of females across all regions through surveys and interviews. A total of 28 data points were collected to determine % of D4Ag users who were female. This was then lowered by 20% to account for the knowledge that innovators who had tracked female users would be more focused on female inclusion outcomes than what is representative. To calculate the total number of females in agriculture, a FAO report was used to determine % of women agricultural employment coupled with farmer estimates listed above.

			Latin America and the Caribbean	Sub-Saharan Africa	South Asia	Southeast Asia	TOTAL
Baseline input	% females employed in agri		40%	47%	32%	38%	**37%**
	No. of agri workers (millions)	TOTAL	389	203	253	97	**5901**
		Female	89	95	81	37	**221**
		Male	30	107	172	60	**36970**
2023 (current estimate)	Adjusted % of D4Ag users who are female		14%	36%	25%	22%	**26%**
	Current % farmers who are active D4Ag users	TOTAL	17%	5%	10%	6%	**8%**
		Female	11%	4%	8%	4%	**6%**
		Male	19%	6%	12%	8%	**10%**
	Current no. of active D4Ag users (millions)	TOTAL	67	11	26	6	**50**
		Female	1	4	7	1	**13**
		Male	6	7	20	5	**37**
	Current no. of non-active D4Ag farmers (millions)	TOTAL	312	192	226	91	**5401**
		Female	78	91	74	35	**2089**
		Male	245	101	152	35	**332**
	Current Gender gap		43%	37%	28%	54%	**42%**
2033 (thriving forecast)	Future % farmers who are active D4Ag users	TOTAL	36%	25%	50%	35%	**38%**
		Female	26%	27%	39%	29%	**32%**
		Male	34%	35%	44%	40%	**40%**
	Future no. of active D4Ag users (millions)	TOTAL	14	51	126	34	**224**
		Female	2	26	32	11	**71**
		Male	10	37	76	24	**148**

2033 (thriving forecast)	Future no. of non-active D4Ag farmers (millions)	TOTAL	245	152	127	63	**3667**
		Female	6	70	49	26	**151**
		Male	1920	70	96	36	**222**
	Future Gender gap		24%	22%	11%	26%	**20%**

Table 22. Women Inclusion in D4Ag

APPENDIX 2. AGBASE TAXONOMY ALIGNMENT

AgBase Taxonomy		
Taxonomy Category	**Definition**	**Advisory & Information**
Agriculture FinTech	In-house financial services offerings for agriculture value chain participants. Examples include digital first finance institutions, payment providers, agriculture insurance companies, and specialized FinTechs providing a broad bundle of services, including advisory and market linkage	Secondary
Agriculture Marketplace	Digital platforms that connect agriculture value chain participants to products or service offerings. Many digital platforms link farmers to input providers, off-takers, wholesalers, and/or bundled service offerings	Secondary
Farm Robotics, Mechanization & Equipment	Hardware solutions including digitally enabled on-farm machinery, automation, and equipment	
Farm Management Services	Digitally-enabled solutions for the management of on-farm activities, including farmers and agri-SMEs. Specific activities include onboarding, profiling, and managing farmers, providing farmers with up-to-date market information and / or advisory services on agricultural practices, and on-farm ag data capturing devices	Secondary
Agroclimatic Risk Intelligence Services and Products	Providers focused on analyzing agroclimatic data for informed decisioning, including agribusiness climate risk, regional agroclimatic risk analysis, market information, conservation, and carbon monitoring	Primary
Food Traceability & Supply Chain Management	Supply chain digitization solutions allowing for tracking and tracing of food products, logistics optimization, or end-to-end value chain production planning and decisioning	
Food Processing Technologies	Digitally enabled solutions to enhance efficiency and sustainability in food processing	
Logistics, Transportation, and Warehousing Infrastructure	Digitally enabled hardware and software solutions to optimize post-farm logistics	
Additional categories to be included in AgBase taxonomy, not covered by scope of report:		
Ag Biotech, Bioenergy & Biomaterials		
Novel Farming Systems		
Innovative Food & Beverages		
Retail & Consumer		
Restaurant & Retail Tech		
Home and cooking tech		

Note:
Primary indicates use cases that are core to the business model of each taxonomy category
Secondary indicates use cases that are often, but not always, included in these business models, in addition to the primary use cases
This taxonomy is still under development and exact categories may change. The grayed out categories indicate additions that will be included in the AgBase taxonomy, but were not covered in this report

Beanstalk Use Cases				
Market Linkage & Access	**Enterprise Management & Efficiency**	**Supply Chain Management**	**Financial Access**	**Enterprise R&D**
			Primary	
Primary			Secondary	
			Secondary	Primary
Secondary	Primary		Secondary	
	Secondary	Primary		
				Primary
		Secondary	Secondary	Primary

Figure 58. AgBase Taxonomy Alignment

APPENDIX 3. ALTERNATIVE FUTURES DETAILED METHODOLOGY

For each dimension, a baseline view was estimated, informed by datasets primarily from FAOSTAT, World Bank and USDA ERA, which were used to project out changes in future. There exists a large data gap at a regional and country level for D4Ag adoption and female adoption rates, which we have supplemented with surveying prominent D4Ag startups across the regions. Despite this, representative and accurate data on D4Ag adoption still remains elusive and estimates were used to forecast current penetration. The model does not take into account any changes to baseline volume of agricultural output that may occur in the future e.g., climate-related impacts on income or demand / policy-driven influences on output. Inflation has also not been taken into account.

The 10-year outlook model looked at several variables for each key aspect across Economic, Gender and Social Equity and Environment. Analysis was aggregated in each region by the various maturity levels of each country (i.e., Leaders, Emergent, and Nascent) as categorized above.

Smallholder farmer estimate

For the purposes of this report, we used Ag Labor estimates from US Department of Agriculture's Economic Research Service (ERS),1 which was sourced from ILO ILOSTAT labor force survey estimates (if available) or modeled estimates (1991+), supplemented with GDCC estimates and previously published FAO estimates (pre-1991).

Region	Maturity Level	Workers in Agriculture (millions)
Latin America and the Caribbean	3 | Leaders	8
	2 | Emergent	12
	1 | Nascent	18
	Total	**38**
Sub-Saharan Africa	3 | Leaders	28
	2 | Emergent	80
	1 | Nascent	95
	Total	**203**
Southeast Asia	3 | Leaders	-
	2 | Emergent	70
	1 | Nascent	27
	Total	**97**
South Asia	3 | Leaders	187
	2 | Emergent	53
	1 | Nascent	13
	Total	**253**
Total		**590**

Table 23. Ag Labor estimates from US Department of Agriculture's Economic Research Service (ERS)

Economic: Additional income enabled by D4Ag in 10 years

We identified six key levers driven by D4Ag that would drive additional income: (1) labor efficiency, (2) input optimization, (3) yield increase from decreased loss of crops, (4) price increase, (5) reduced equipment maintenance, and (6) carbon credit market. For levers 1–5, we identified the baseline, adoption percentage of these D4Ag tools and multiplied through by impact percentage over 10 years.credits were assumed to be priced at US$15/MtCO2.5[5]

The following absolute lift in adoption rates over 10 years were assumed.

Economic Lever	Maturity	Absolute % lift in adoption over 10 years	
		THRIVING SCENARIO	DERAILING SCENARIO
ALL D4AG (LEVERS 1-5)	Leaders	40%	13%
	Emergent	30%	8%
	Nascent	20%	4%
CARBON CREDIT (LEVER 6)	Leaders	15%	5%
	Emergent	10%	3%
	Nascent	5%	2%

Table 24. Adoption Rates Assumptions

For Lever 6, carbon credit market, a different methodology was used. It was assumed that carbon is earned via two avenues: carbon sequestered by soil (capturing 0.8 MtCO2 per ha2) and carbon sequestered by planted forests (capturing 10 MtCO2 per ha3). The percentage lift in adoption rates as seen above were applied to total agricultural land4 for soil sequestration, and only ~8% of the land belonging to farmers who have chosen to participate in the carbon credit market was assumed to have trees planted on it. Carbon credits were assumed to be priced at US$15/MtCO2.5

The following tables outline the impact assumptions underlying the analysis. For the derailing scenario, it was assumed that only half of the impact would be captured, except for the reduction in animal and aquaculture mortality where only a third of the impact is assumed to be captured compared to the thriving scenario.

THRIVING SCENARIO					
Economic Lever		Metric	10-year impact for adopters (%)		
			Leaders	Emergent	Nascent
1. LABOR EFFICIENCY		% labor saved	15%	30%	40%
2. INPUT OPTIMISATION	Animal Feed	feed conversion ratio improvement	10%	15%	20%
	Fertiliser	% fertiliser input reduced	20%	30%	40%
3. YIELD INCREASE	Crops	See outlined below			
	Animals	% reduction in animal mortality	30%	30%	30%
	Aquaculture	% reduction in Aquaculture mortality	30%	30%	30%
4. PRICE INCREASE		% price increase (better quality and increase market access)	16%	21%	26%
5. REDUCED EQUIPMENT MAINTENANCE		% change in 10 years	10%	20%	30%

Table 25. Future Outlooks Assumptions

DERAILING SCENARIO					
Economic Lever		Metric	10-year impact for adopters (%)		
			Leaders	Emergent	Nascent
1. LABOR EFFICIENCY		% labor saved	8%	15%	20%
2. INPUT OPTIMISATION	Animal Feed	feed conversion ratio improvement	5%	8%	10%
	Fertiliser	% fertiliser input reduced	10%	15%	20%
3. YIELD INCREASE	Crops	See outlined below			
	Animals	% reduction in animal mortality	10%	10%	10%
	Aquaculture	% reduction in Aquaculture mortality	10%	10%	10%
4. PRICE INCREASE		% price increase (better quality and increase market access)	8%	11%	13%
5. REDUCED EQUIPMENT MAINTENANCE		% change in 10 years	5%	10%	15%

Table 25. Future Outlooks Assumptions

The yield increase was estimated by leveraging the yield gap6 and assuming 8%–20% of the yield gap is captured over 10 years in the thriving scenario, with the derailing scenario only seeing a third of the impact compared to the thriving scenario.

ENVIRONMENT

For the thriving scenario, we calculated the GHG emissions by identifying five key levers of reduction: (1) Reduced animal gases (2) Greater fuel efficiency for on-farm machinery and equipment (3) Improved rice cultivation (4) Efficient synthetic fertilizer usage (5) Regenerative forestry and soil practices. For Levers 1–4, we used FAOSTAT Emissions Totals10 to establish the baseline GHG emissions for each lever. Our team assumed an adoption rate and multiplied it by estimates of GHG reduction potential. For GHG emissions from regenerative forestry and soil practices, the same calculations as the Economic section Lever 6. Carbon Credit Market was used to determine the amount of carbon sequestered by soil and trees. See below for a summary of assumptions used.

THRIVING SCENARIO					
GHG Reduction Lever		Absolute % lift in adoption over 10 years (%)			10-year impact for adopters (%)
		Leaders	Emergent	Nascent	
1. REDUCE GASES FROM ANIMALS		20%	15%	10%	20%
2. GREATER FUEL EFFICIENCY		30%	23%	15%	65%
3. IMPROVE RICE CULTIVATION	Southeast Asia	40%	30%	20%	81%
	Others	24%	18%	12%	81%
4. EFFICIENT SYNTHETIC FERTILIZER USAGE		15%	11%	8%	21%

Table 26. Future Outlooks Assumptions

For the derailing scenario there were two main drivers that were included in GHG increase: (1) increased fuel usage from tractors and (2) increased fertilizer usage. For the first lever, we estimated the increase to GHG emissions from farm energy for each country by calculating the gap between agricultural machinery per ha and the US average of 271 tractors per ha11(Latest year of available information was 2007). We only assumed 60% of the gap was captured, to calculate the estimated increase in machinery and subsequently greenhouse gases. This may occur regardless in the thriving scenario; however, it may be likely that equipment with lower carbon footprint may be increasingly used over fuel-based ones.

For increased synthetic fertilizer usage, a similar approach was adopted determining the gap between fertilizer application per hectare of land in each country and average fertilizer application amount which was 165 kg per hectare of arable land in 2020.12 Again, we assumed only 60% of this gap was captured, and the increase in additional fertilizer application required was applied to current GHG emissions from synthetic fertilizer to determine the increase in GHG emissions.

APPENDIX 4. REGIONAL D4AG PROFILES

Sub-Saharan Africa

ROLE OF AGRICULTURE AND SMALLHOLDER FARMERS IN SUB-SAHARAN AFRICA

Smallholder agriculture is of immense importance for sub-Saharan Africa, representing both a vital source of livelihood and a crucial component of the region's economic resilience. In an area where farming is often the primary means of subsistence, smallholders contribute significantly to food security by producing a substantial proportion of the region's food supply.

Agriculture Sector Contribution to GDP	Agriculture Sector Contribution to Sector Employment	Key Crops
17.2%[61]	52.8%[62]	Maize, Sweet potato, Rice, Cassava, Wheat, Fruits & Vegetables, Cocoa
Average Size of a Smallholder Farm	**Number of Smallholder Farmers**	**Share of Female Workers**
<1 ha[63]	~ 190 million %[64]	40-50%[65]

Table 27. Role of Agriculture in sub-Saharan Africa

61 World Bank Data, "Agriculture, forestry, and fishing, value added (% of GDP)", 2021
62 World Bank Data, "Employment in Agriculture (% of total employment)", 2021
63 Giller, K.E., Delaune, T., Silva, J.V. et al. Small farms and development in sub-Saharan Africa: Farming for food, for income or for lack of better options?. Food Sec. 13, 1431–1454 (2021). https://doi.org/10.1007/s12571-021-01209-0
64 CTA 2019
65 Kudama, Gezahagn, Mabiratu Dangia, Hika Wana, and Bona Tadese. "Will digital solutions transform Sub-Sahara African agriculture?." Artificial Intelligence in Agriculture 5 (2021): 292-300.

D4AG REACH AND ADOPTION PROGRESS IN SUB-SAHARAN AFRICA

Sub-Saharan Africa accounted for a whopping 49% of all D4Ag solutions we have identified in LMICs: as of 2022, there have been at least **666 active D4Ag** solutions operating in the region. As found in the CTA 2019 report, the sector was and remains young, as **at least 32% of innovations have been launched after 2018,** however we have identified at least 60 solutions that went inactive in the past 5 years.

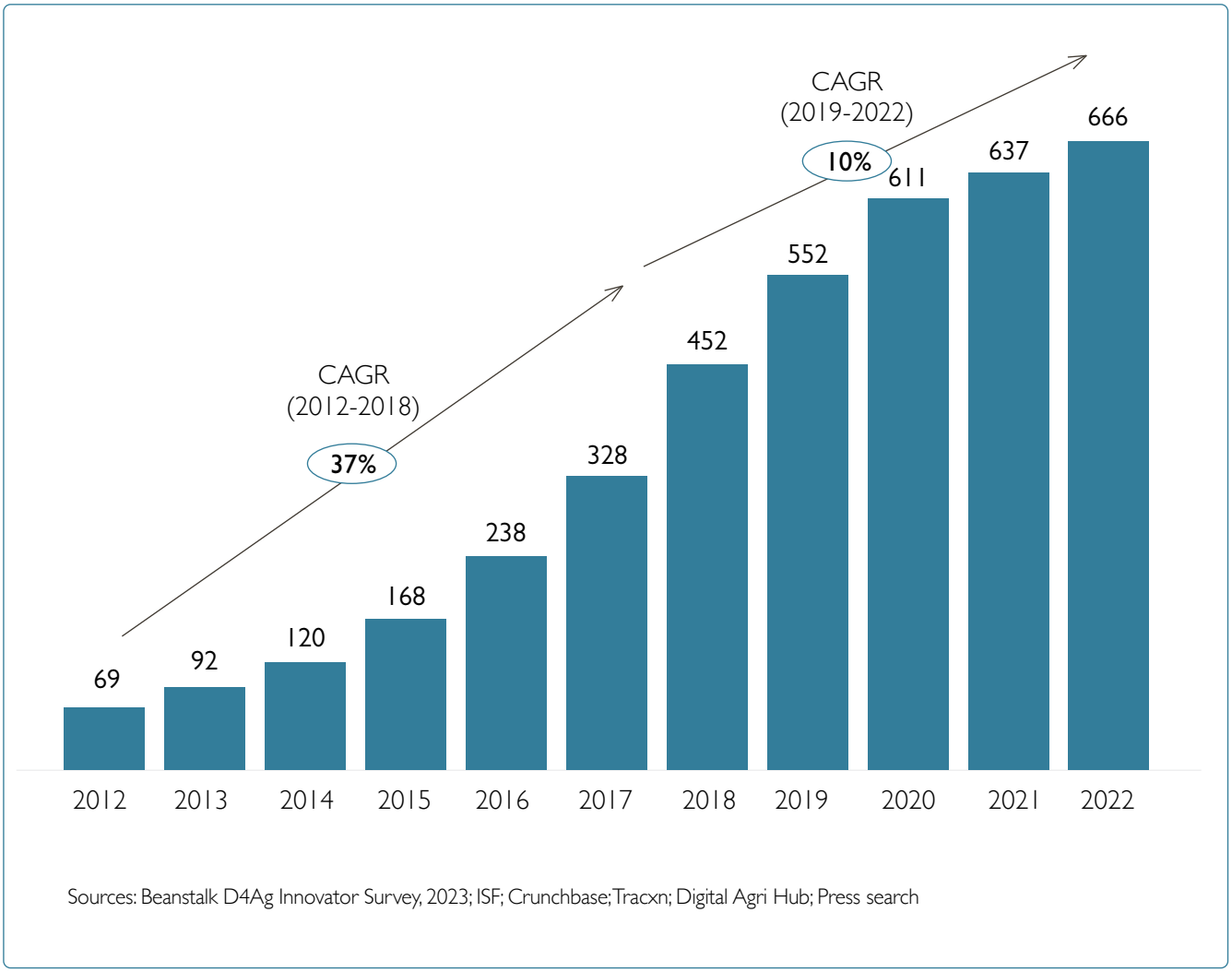


Figure 59. Number of Active D4Ag Solutions (sub-Saharan Africa), 2012 – 2022

The economics of these businesses are improving: according to our interviewees, **39% of them are breaking even, versus 26% estimated by the CTA five years ago**, demonstrating a positive trend towards more commercial stability.

The geographical reach is expanding but remains concentrated: even though we have **identified 36 countries in the region with at least one D4Ag solution being present**, more than **45% of the D4Ags are headquartered in Kenya or Nigeria** – the regional D4Ag hubs, and almost two-thirds are concentrated in the top five markets (Kenya, Nigeria, South Africa, Ghana, and Uganda).

Investments in D4Ag are on the rise, but the region remains the least funded across the LMICs: in 2021, sub-Saharan African innovators have raised $312 million from private investors.[66] Importantly, the region remains dominated by donors, with three quarters of our respondents admitting that they have relied on donor funding.

Number of active D4Ag solutions (2022)	666
Number of active D4Ag solutions (2018)	452
Most commonly observed use case	Market Linkages & Access (35%)
Median number of users per solution	60,000 (N=86)
Proportion of innovators breaking even	39%

Table 28. D4Ag Reach and Adoption in sub-Saharan Africa
Source: Beanstalk KIIs and D4Ag Innovators Surveys, 2023

Source: Feed the Future Flickr. Photo credit: Benjamin Drummond

66 AgFunder Africa AgriFoodTech Investment Report 2023. (Only D4Ag solutions included in the number)

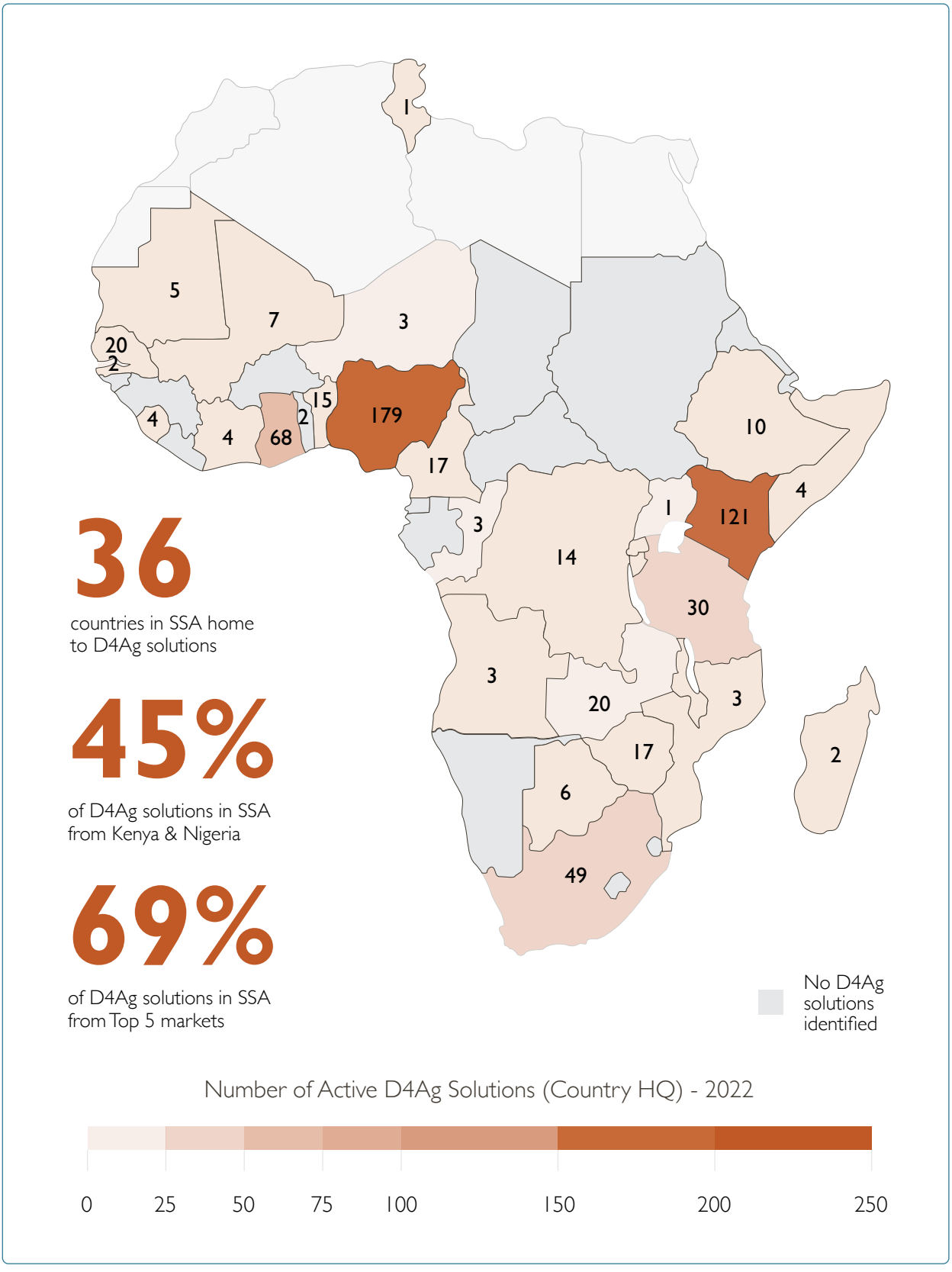


Figure 60. Number of Active D4Ag Solutions, by Country HQ in sub-Saharan Africa, 2022

Despite only 20% of startups expanding operations out of their home country, this is a larger proportion than in South Asia or Latin America, where less than 8% operate in multiple countries.

As of 2022, 56% of innovators focus on either 'Market Linkages' or providing 'Advisory and Information' services. There's also a clear trend toward bundling of service offerings, with almost 40% of D4Ag innovators now offering more than one service.

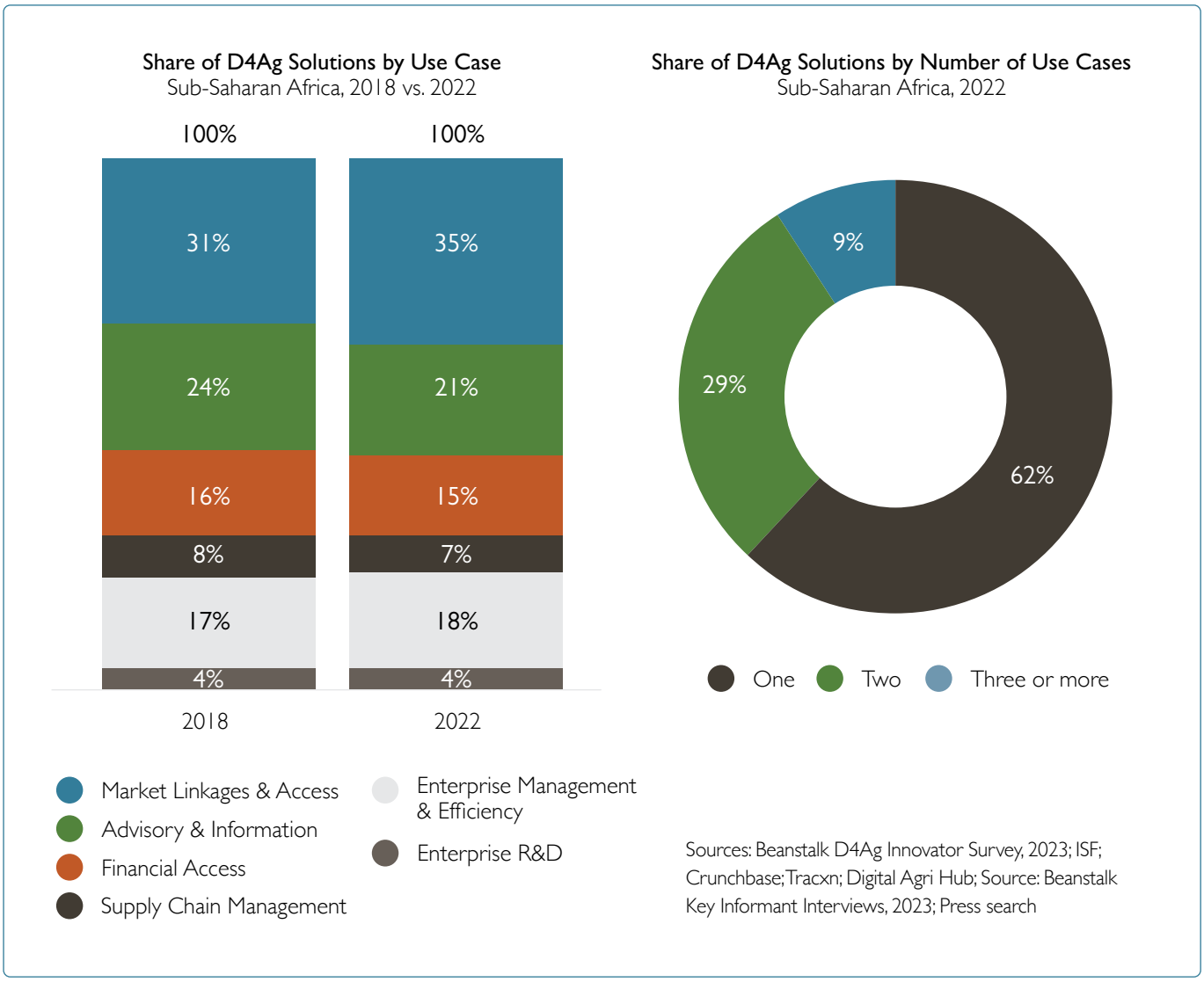


Figure 61. Mix of Use Cases Across D4Ag Solutions (SSA, % of Total)

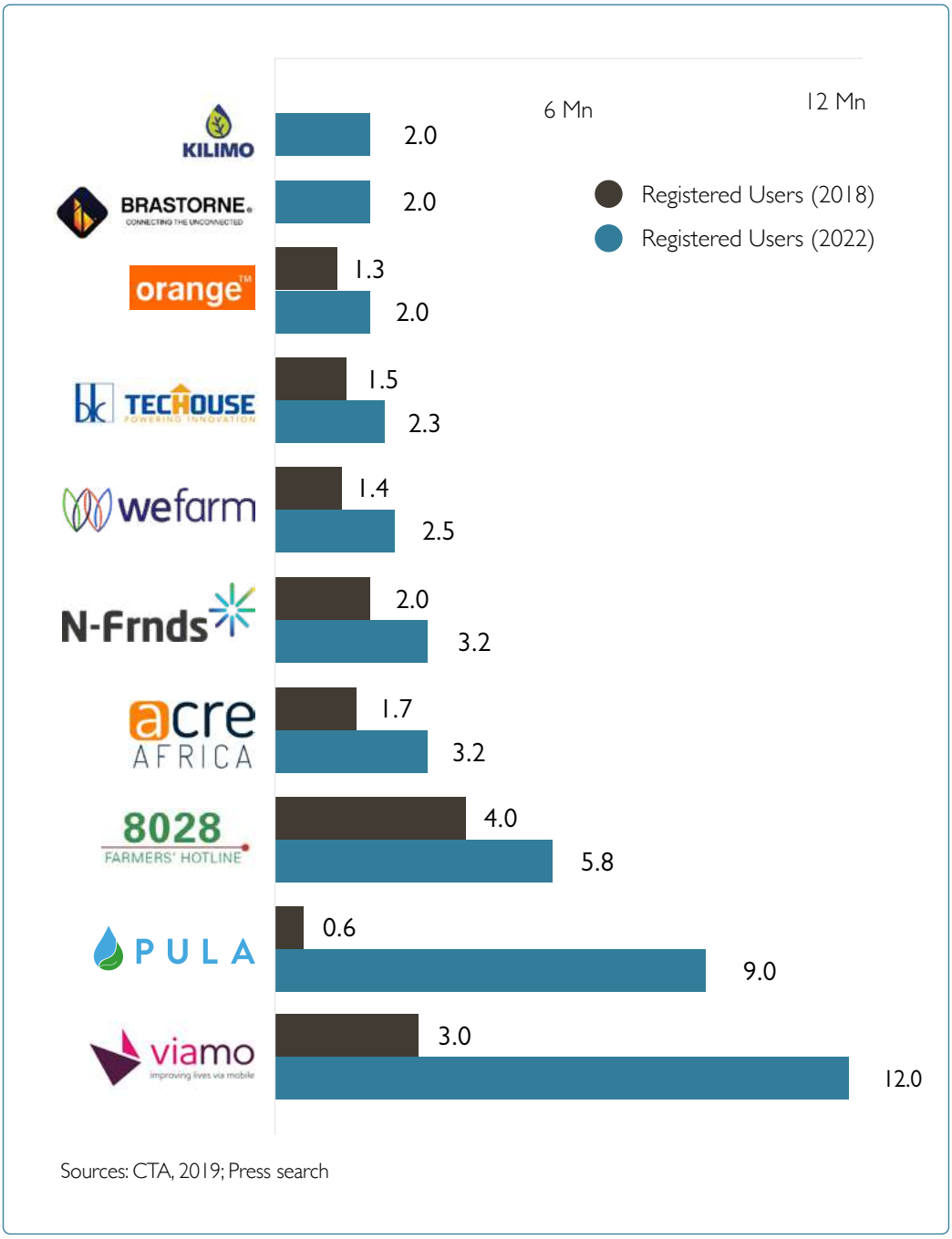


Figure 62. Registered Users of Top 10 D4Ag Solution Providers, SSA.

Regarding user adoption, there has been substantial growth over the past five years. In 2022, **27 solutions reached the 1 million user mark, up from just 11 in 2018.** Even newer innovators are experiencing significant growth in their user base: the majority of D4Ag innovators now have between 1,000 and 50,000 users, with a median number of registered users per solution standing at 60,000 smallholder farmers.

Investment landscape in sub-Saharan Africa is very nascent in comparison to other LMICs: the region has attracted the lowest level of VC investments across LMICs, despite being home to a sixth of the population. Access to funding was the second most referenced barrier that D4Ag innovators are facing in the region, after access to skilled talent: **39% of innovators admitted facing lack of access to investments.** Nevertheless, few standout startups have raised substantial capital and expanded into different markets: **ten solutions managed to raise over US$10 million each in total funding from private investors.**

	Solution Name	Total Funding (US$, Mn)	Stage	HQ Country	Operations
1	Twiga Foods	**$ 157.1**	Series C		
2	Apollo Agriculture	**$ 61.7**	Series B		
3	Thrive Agric	**$ 60**	Debt		
4	Komaza	**$ 58.6**	Series B		
5	SunCulture	**$ 37.3**	Debt		
6	WeFarm (shut down)	**$ 32.0**	Series A		
7	Aerobotics	**$ 26.8**	Series B		+17
8	iProcure	**$ 16.8**	Debt		
9	Farmerline	**$ 15.2**	Seed		+4
10	Pula Advisors	**$ 10**	Series A		+8

Source: Crunchbase

Table 29. Top 10 Solutions by Total Amount of Private Funds Raised, 2022, sub-Saharan Africa, (US$, Mn).

Interestingly, the leaders in terms of number of users are usually not among the fundraising champions: only **Pula** and now out-of-business **WeFarm** have made it to both top-10 lists, showing that, while user numbers are an important metric, they do not always correlate with fundraising success.

ENGAGING YOUTH IN D4AG IN SUB-SAHARAN AFRICA

Special attention in sub-Saharan Africa has been brought to the engagement of youth in D4Ag, as the region is home to the world's youngest population with 2 out of 3 inhabitants of SSA being under the age of 30. This expanding youth population presents both an opportunity and a challenge: on the one hand, it signifies a dynamic and vibrant workforce that, while on the other hand, creates a potential for escalated unemployment and social instability.

The whole agricultural value chain, from production to processing, marketing, and consumption, offers a plethora of opportunities for young people, who can effectively utilize digital tools for various agricultural activities, from accessing weather data, managing farms, **linking with markets, to utilizing financial services.** D4Ag can create

significant employment and entrepreneurship opportunities for youth, besides just farming, in areas such as software development, data analytics, drone operation, or digital extension services.

We have observed an emerging trend in sub-Saharan Africa where innovators like **E-Vuna, MyAgro**, and others are focusing on equipping young individuals to act as 'village-based advisors'. This concept involves empowering the youth with the necessary skills and tools to provide various digital agriculture services within their communities. Not only does this model provide the youth with an avenue for employment and entrepreneurship, but it also positions them as key contributors to their communities' agricultural development. Engaging in these advisory roles does not necessarily exclude the possibility of these young individuals participating in farming activities, in fact, combining these roles can enhance their understanding of practical farming challenges and allow them to offer more relevant and pragmatic advice. By fully embracing this model, innovators not only create an attractive and meaningful livelihood option for the youth but also foster a community-driven approach to advancing digital agriculture.

BUILDING CLIMATE CHANGE ADAPTATION & RESILIENCE IN SUB-SAHARAN AFRICA

Climate-smart D4Ag is of immense importance to sub-Saharan Africa, a region particularly vulnerable to climate change. Especially relevant is the threat of recurrent and severe droughts that put strain on water resources and undermine agricultural productivity. In this context, D4Ag holds immense promise for improved irrigation management and drought mitigation. However, the usual barriers such as limited digital literacy, inadequate infrastructure, and high costs of technology hamper the reach of climate-smart digital technologies in the region and the adoption remains very low. Nevertheless, SSA has seen a surge in innovative startups employing digital tools for climate-smart agriculture, specifically focusing on mitigating drought impacts and optimizing irrigation.

Source: Feed the Future Flickr. Photo credit: Imran Abdullahi

Ignitia is a social enterprise that provides hyper-local weather forecasts via SMS to small-scale farmers in West Africa. Using proprietary algorithms designed for the tropics, Ignitia's forecasts help farmers make critical decisions—like when to plant, irrigate, or harvest—to improve crop yields and reduce loss, contributing to enhanced climate resilience.

SunCulture has developed the RainMaker2 solar-powered irrigation system, which combines cost-effective solar pumping technology with a high-efficiency drip irrigation system. Their product enables farmers to grow high-quality produce all year round, and their "Pay-As-You-Grow" platform makes the technology accessible to even smallholder farmers. This improves farm productivity, income, and aids in the adoption of climate-smart practices.

Tolbi has developed a real-time digital decision-making platform that includes mobile agriculture and digital profiling of farmers for proper campaign management, irrigation water and fertilization control, and remote farming practices. Their platform offers localized advisory, AI-based plant disease management, yield forecasts and water needs analysis.

AgriPredict offers a digital platform that provides farmers with various services, including disease and pest identification, weather forecasts, and market information. Notably, it uses AI to predict the likelihood of pest invasions or disease outbreaks, helping farmers preemptively mitigate these risks and thus bolstering their climate resilience.

Figure 63. Sub-Saharan African Climate-Smart D4Ag Innovators

FUTURE OUTLOOKS

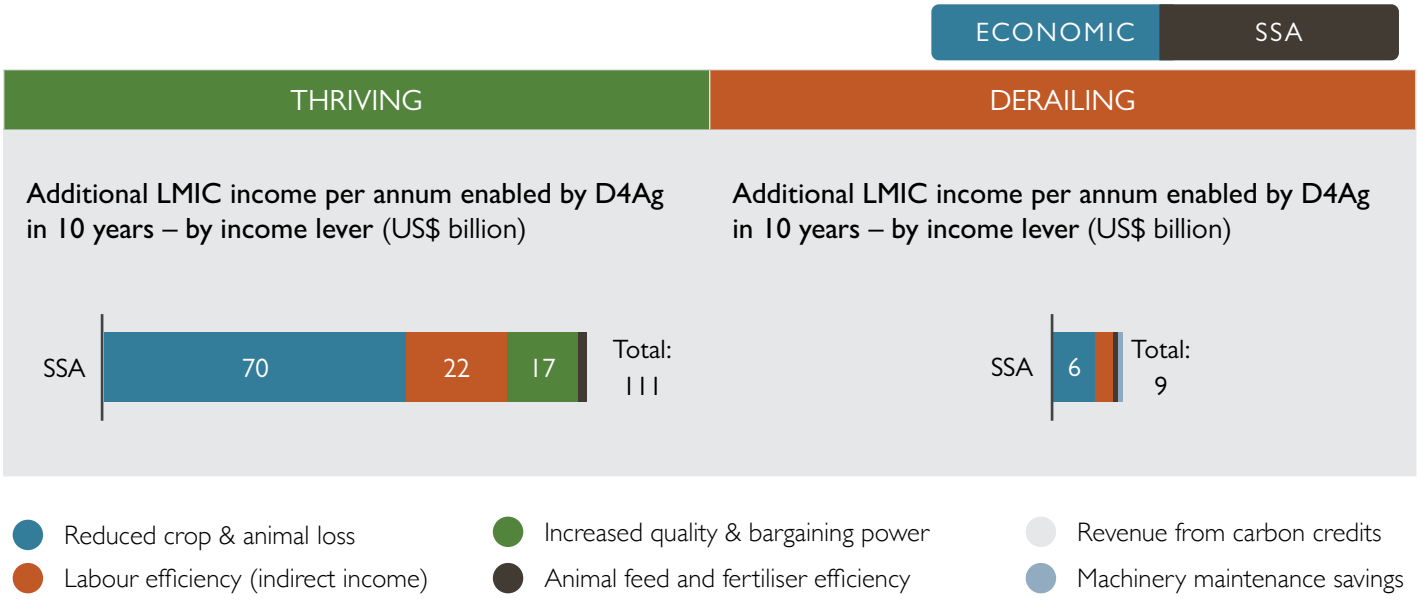
The unfolding decade presents both challenges and opportunities for the D4Ag sector. As the world grapples with rapid technological advances, climate change, and evolving socio-economic dynamics, the D4Ag stands poised to play a transformative role, especially in LMICs. To capture this potential, we have meticulously analyzed and projected the future course of the sector and its impact across three impact vectors: economic, social, and environmental.

	Economic Projections (Additional LMIC income per annum enabled by D4Ag)	Social Projections (% of potential user base actively using D4Ag)	Environmental Projections (D4Ag-enabled farm-gate GHG change per annum)
Thriving Scenario	US$111 billion	25%	-62 CO2eq megatons
Derailing Scenario	US$9 billion	11%	+70 CO2eq megatons

Table 30. 10-Years Outlook for the Sector: Sub-Saharan Africa

Economic Projections:

In the "thriving" scenario, sub-Saharan Africa is projected to generate an additional income of US$111 billion enabled by D4Ag over the next decade. In the "derailing" scenario, the region may only witness less than 10% of the potential additional income.

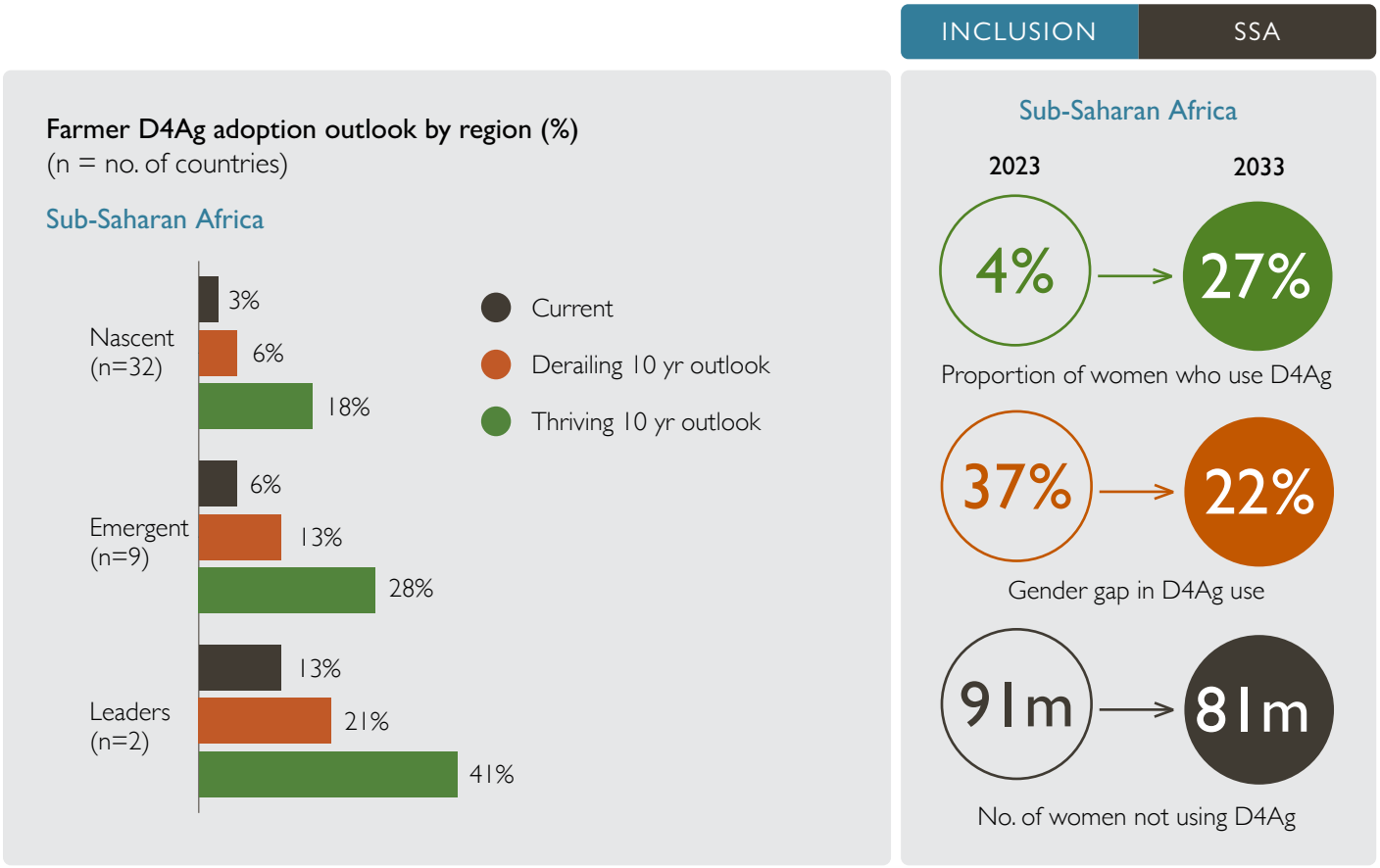


Source: USDA ERS International Agricultural Productivity indices, Beanstalk analysis

Figure 64. Economic Projections Sub-Saharan Africa

Social Projections:

Currently D4Ag adoption stands at an average of 5% in sub-Saharan Africa. The level of adoption varies within sub-Saharan Africa, depending on the maturity of D4Ag ecosystems. By the end of the decade, regional leaders like Kenya and Nigeria could see an uptake of 41%, if they thrive. The potential benefits might also extend to 'Nascent' countries, with up to 20% of their farmers adopting D4Ag solutions. Moreover, the 'thriving' scenario could lead to 1 in 3 females in agriculture using D4Ag tools, reducing the gender gap by half.

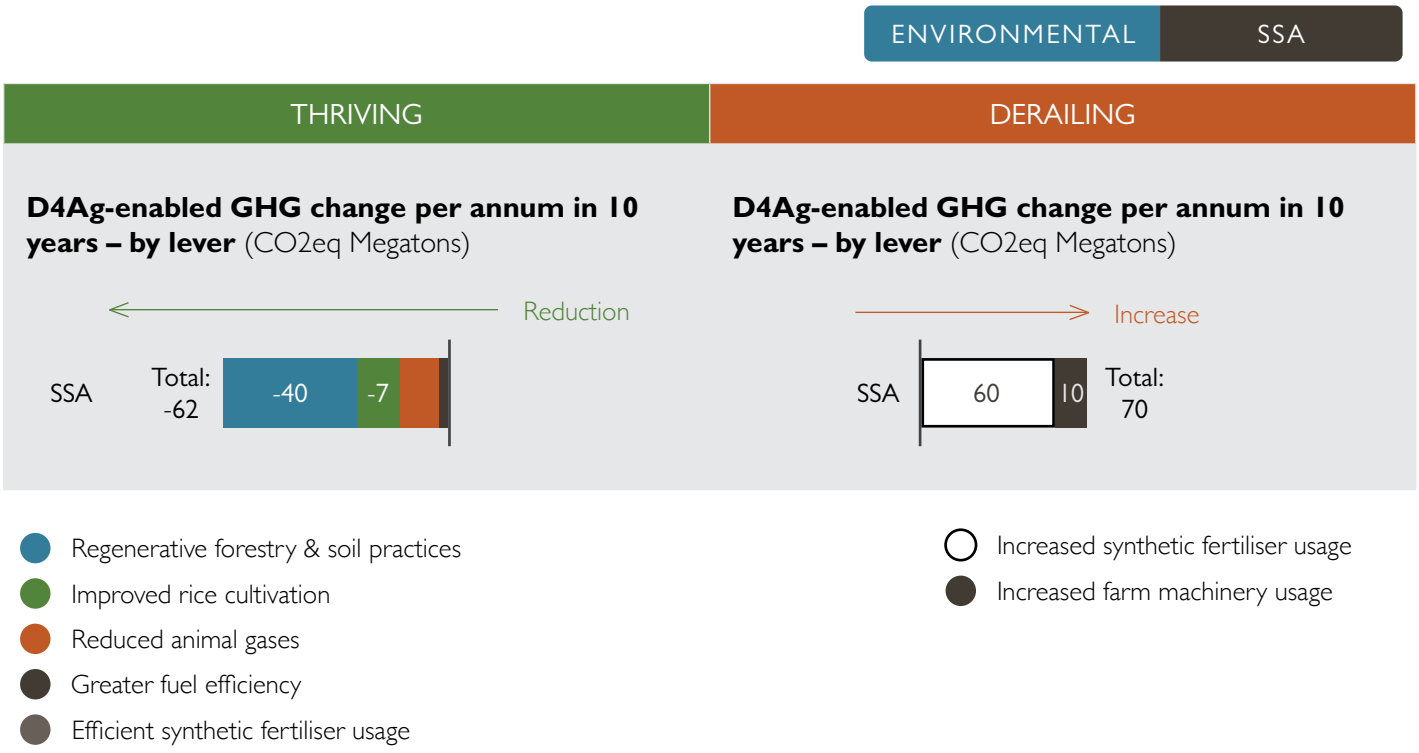


Note: Available data was extremely limited. Available country data was extrapolated to represent the entire progression status per region. Where data was not available, the 2016 Digital Adoption Index (DAI) was utilized to estimate current adoption levels. The thriving scenario was projected by using the internet adoption curves of each country with an adjustment factor. Relative to internet adoption, the following lag was assumed for D4Ag adoption: Leaders – 10-year lag, Emergent – 12-year lag, Nascent – 15-year lag.

Source: Various, World Bank World Development Indicators (Individuals using the Internet (% of population)), Beanstalk analysis

Figure 65. Social Projections Sub-Saharan Africa

Environmental Projections:
In a thriving ecosystem, regenerative forestry and soil practices are key drivers for environmental impact in sub-Saharan Africa, contributing to 40 out of 60 CO2eq Megatons decrease in annual GHG emissions. Conversely, in a 'derailing' scenario, the region could experience an increase in GHG emissions (71 Megatonnes CO2eq), predominantly due to increased synthetic fertilizer usage.



Source: FAOSTAT domain Emissions Totals (last updated 22 May 2023), Beanstalk analysis

Figure 66. Environmental Projections Sub-Saharan Africa

Southeast Asia

ROLE OF AGRICULTURE AND SMALLHOLDER FARMERS IN SOUTHEAST ASIA

The agriculture sector plays a pivotal role in Southeast Asia's economy and society. According to the World Bank, agriculture accounted for about 12% of ASEAN's GDP in 2020, while in countries such as Cambodia and Myanmar, the number reached 20%. Agriculture is also a major employer in the region: in 2021, it accounted for more than 38% of total employment in countries like Laos, Myanmar, Cambodia, and Timor-Leste. Smallholder farmers form the backbone of the region's agriculture, maintaining the diversity of the food system, preserving traditional farming practices and contributing to regional food security.

Agriculture Sector Contribution to GDP	Agriculture Sector Contribution to Sector Employment	Key Crops
12.23% [67]	28.18%[68]	Rice, Sugarcane, Soybean, Coconut, Rubber, Cassava
Average Size of a Smallholder Farm	**Number of Smallholder Farmers**	**Share of Female Workers**
<1.5 ha[69]	~ 100m[70]	46%[71]

Table 31. Role of Agriculture in Southeast Asia

67 World Bank Data, "Agriculture, forestry, and fishing, value added (% of GDP)", 2021
68 World Bank Data, "Employment in Agriculture (% of total employment)", 2021
69 FAO: Family Farming Knowledge Platform, 2023
70 Climate Focus news report, 2021
71 Asian Development Blog, 2015

D4AG REACH AND ADOPTION PROGRESS IN SOUTHEAST ASIA

The D4Ag landscape in Southeast Asia presents a unique combination of challenges and opportunities. Farmers in the region have demonstrated a strong interest in digital learning, with social media and other digital communication channels, such as Facebook and WhatsApp, playing a significant role in knowledge exchange thanks to the highest levels of internet connectivity across low- and middle-income regions. Peer-to-peer learning through these platforms has become a key information source for farmers, supplementing traditional methods and filling gaps where extension services may be lacking.

Moreover, large agribusinesses in the region are progressively employing digital tools for diverse functions including record-keeping, traceability, and managing their suppliers and customers. Companies like **CropIn** and **Koltiva** are exemplary of this trend, having gained substantial traction in the region. However, while these developments are encouraging, their impact on smallholder farmers remains limited.

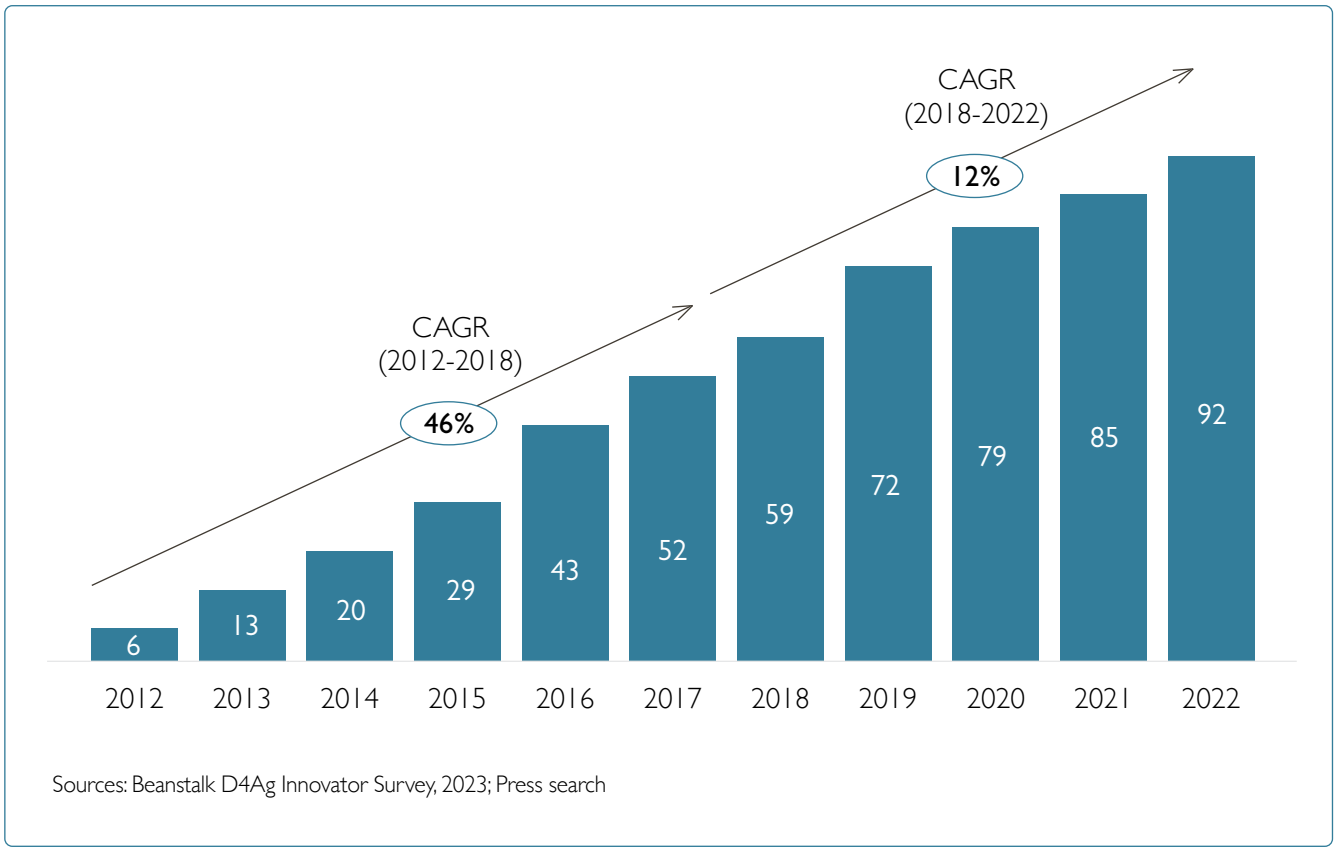


Figure 67. Number of Active D4Ag Solutions in Southeast Asia, 2012-2022

In fact, the penetration of farmer-facing digital tools in Southeast Asia is relatively low. According to a survey conducted by Grow Asia in 2019,[72] over 90% of farmers have used a phone to call a transaction party, but less than 1% have ever downloaded a farmer service app. This reflects the persistent barriers to technology adoption among smallholder farmers, which may include factors such as limited digital literacy, infrastructural issues, and a lack of suitable and user-friendly solutions. Our findings further corroborate this reality, with only 7 solutions in the region having reached at least 100,000 registered users as of 2022. Even the largest solutions in terms of reach currently do not serve more than 10-15% of smallholder farming population in their countries.

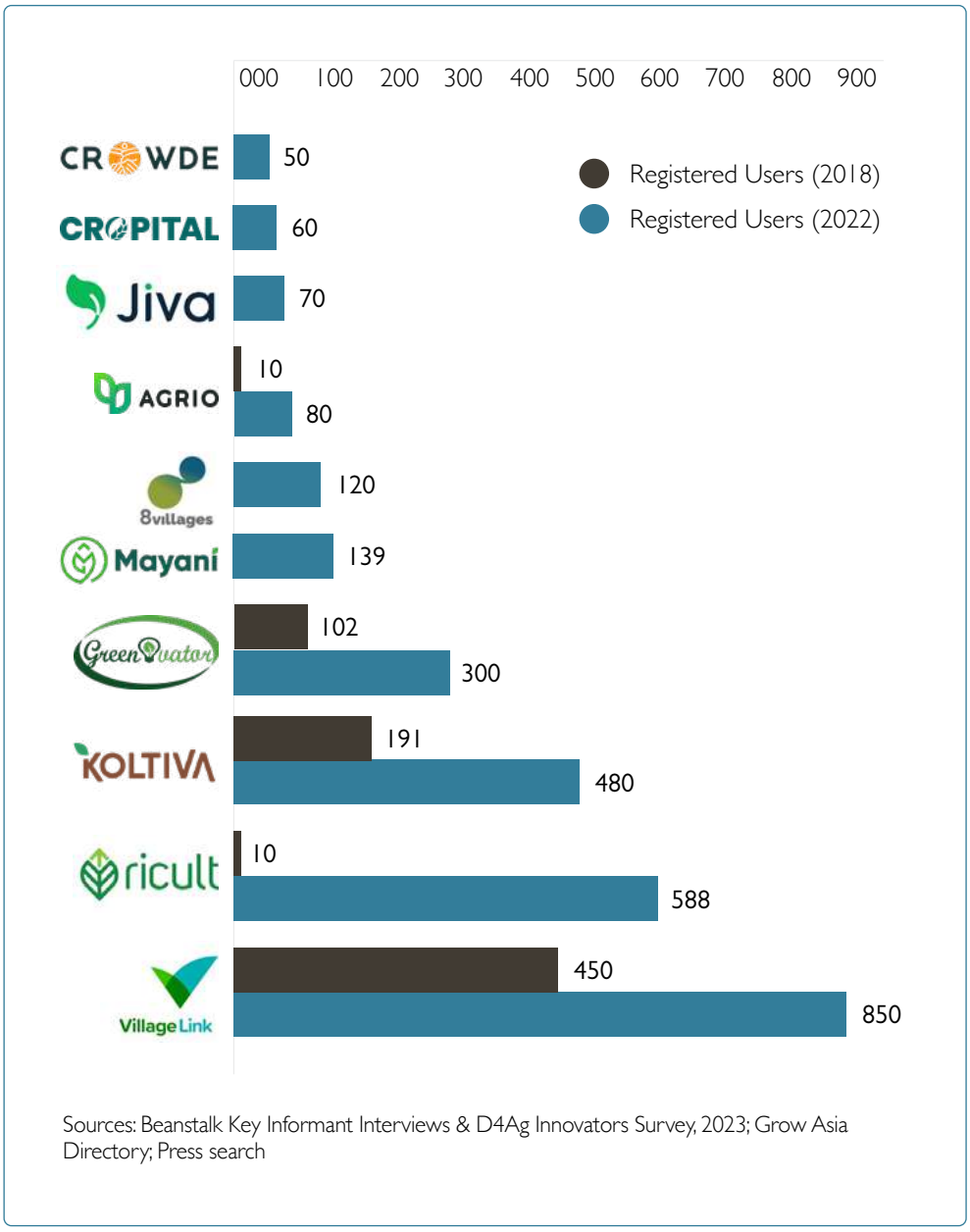


Figure 68. Registered Users of Top-10 D4Ag Solutions. Southeast Asia, 2022

72 GrowAsia: Driving AgriTech Adoption: Insights from Southeast Asia's Farmers, 2019

Number of active D4Ag solutions (2022)	92
Number of active D4Ag solutions (2018)	59
Most commonly observed use case	Advisory & Information (24%)
Median number of users per solution	57,500
Proportion of innovators breaking even	36%

Table 32. D4Ag Reach and Adoption in Southeast Asia
Source: Beanstalk KIIs and D4Ag Innovators Surveys, 2023

However, the D4Ag ecosystem in Southeast Asia is not static and has seen some development in recent years, and the adoption is estimated to be on the rise. **As of 2022, there have been at least 96 active D4Ag solutions operating in the region, as compared to 72 back in 2019**. Levels of mobile connectivity have been increasing steadily, with 68% of the region's population now using mobile internet, and only 2% not being covered by mobile broadband—the lowest number across LMICs. Moreover, improving device ownership rate have created additional tailwinds for D4Ag adoption: As of 2022, 68% of Indonesia's population, for example, have owned smartphones, as compared to 60% in 2019.[73]

According to our interviewees, **only 36% of them are currently breaking even—the lowest number for commercial stability across LMICs,** also demonstrating overall lower maturity of the ecosystem in the region.

While the geographical reach of these solutions is expanding, it remains largely concentrated in countries like Indonesia, Vietnam, and Thailand, which have emerged as regional D4Ag hubs. Besides, Singapore has emerged as a vibrant hub for agritech startups and innovations, even though its agricultural landscape is extremely limited. Startups are not only attracted by the easy access to capital, but also by the opportunities for collaboration and partnerships with research institutions and established businesses. Singapore's strategic geographic location, positioned in the heart of Southeast Asia, enables it to serve as a gateway to the region's large and diverse agricultural sector. This allows startups based in Singapore to tap into the broader Southeast Asian market, testing and scaling their innovations across different contexts.

Source: Tepbac

73 https://newzoo.com/insights/rankings/top-countries-by-smartphone-penetration-and-users

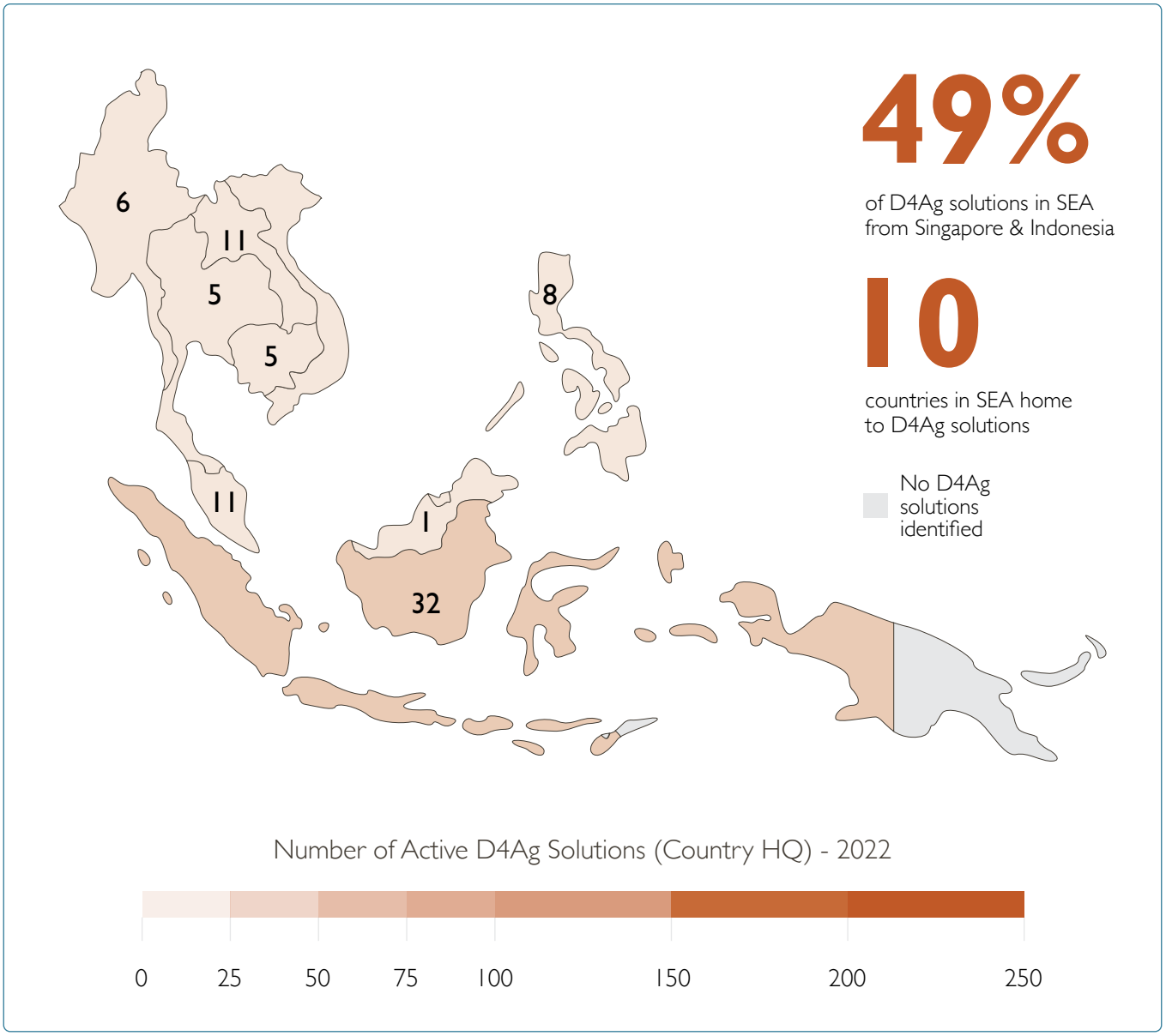


Figure 69. Number of Active D4Ag Solutions, per Country HQ, SEA, 2022

Regarding the most popular use cases, 'Advisory & Information' along with 'Market Linkages & Access' account for roughly half of solutions currently active in the region, mirroring the global trend. Interestingly, almost a quarter of innovators are focusing on offering Enterprise Management services, which is probably due to the important role of large corporate agribusiness in the region, as mentioned earlier.

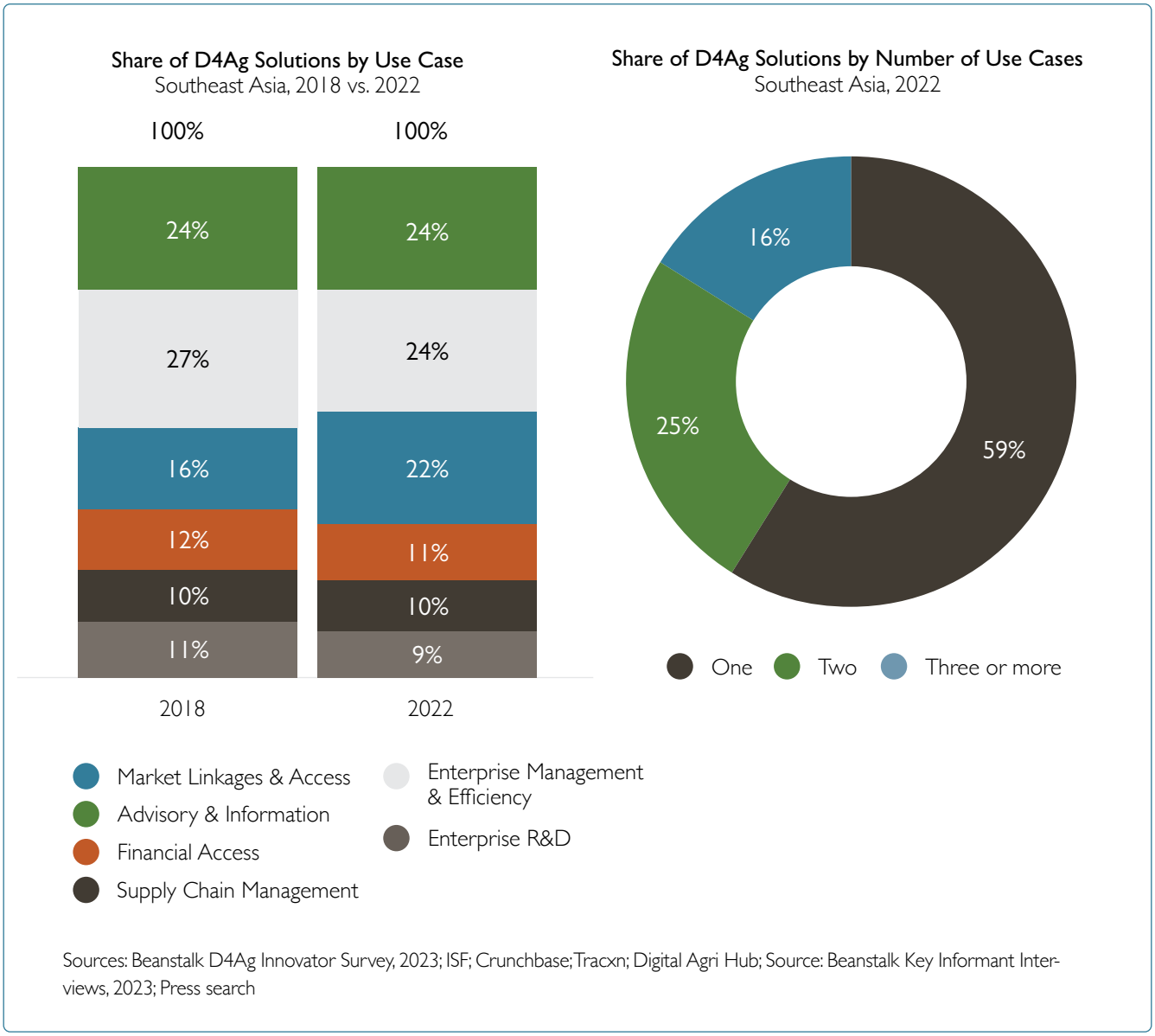


Figure 70. Number of Active D4Ag Solutions, Per Country HQ, SEA, 2022.

Investments in D4Ag in Southeast Asia have been growing steadily, and Indonesia has particularly stood out as an undisputed regional investment hub: All top-10 largest investment rounds of D4Ag startups in the region went to the Indonesian innovators. **In total, innovators in LMICs of APAC (outside China and India) have raised around US$765 million in funding from private investors in 2021**.[74] This promising trend could potentially lead to an acceleration of innovation and growth in the region's D4Ag sector.

74 AgFunder APAC 2021 Investment Report (data for D4Ag innovators in LMICs, ex-India and China – Beanstalk estimates)

	Solution Name	Total Funding (US$, Mn)	Stage	HQ Country	Operations
1	eFishery	**$ 342.9**	Series D		
2	Sayurbox	**$ 139.2**	Series C		
3	Aruna	**$ 100**	Series A		
4	Tani Hub [shut down]	**$ 94.5**	Series B		
5	AgriAku	**$ 46**	Series A		
6	EdenFam	**$ 34.2**	Series B		
7	Pitik	**$ 14**	Series A		
8	Jala Tech	**$ 12**	Series A		
9	CROWDE	**$ 10**	Series B		
10	KedaiSayur	**$ 8.8**	Series A		

Source: Crunchbase

Table 33. Top 10 Solutions by Total Amount Of Private Funding Raised, 2022, SEA, (US$, Mn)

Outside of Indonesia and Singapore, the investment activity has been much more modest: for example, Vietnamese **Tepbac** and Philippines-based **Mayani** have managed to raise US$ 2.3 and US$ 1.7 million Seed rounds respectively.

HARNESSING SOUTHEAST ASIA'S DIVERSITY FOR EFFECTIVE D4AG DEPLOYMENT

Southeast Asia presents a distinct landscape of opportunities and challenges for D4Ag due to its diverse culture, geography, and the infrastructural disparities across the region.

Language Barriers: Southeast Asia is a linguistic tapestry with hundreds of languages spoken across the region. Only in Indonesia there are more than 700 living languages, making it one of the most linguistically diverse countries in the world. This presents a significant challenge for the deployment of D4Ag technologies. For these tools to be effective, they must be adapted to local languages to reach the intended recipients and to be understood. Designing linguistically sensitive D4Ag solutions is not just about translation, but also requires contextual understanding and relevance. Technologies must be designed and implemented with a deep understanding of local idioms, agricultural terminology, and cultural nuances; and ongoing support and training must be multilingual to engage with a wider farming community effectively.

Myanmar-based **Greenovator** faced the problem of language barriers in rural communities of the country, where more than 100 languages are spoken across its 135 ethnic groups. After meeting with the minorities representatives, the team has decided to convert the content into a voice-based format in Burmese; even though many minorities are not able to read in it, they understand the spoken language, and this was a more cost- and time-effective approach to improving the inclusivity of their solution.

Cultural Differences: The region's rich cultural diversity also introduces complexities in the adoption and effectiveness of D4Ag technologies. Different ethnic and indigenous communities often have unique agricultural practices rooted in their traditional knowledge systems that vary considerably from mainstream techniques. For D4Ag to be effective and adopted widely, it needs to recognize, respect, and incorporate these unique practices rather than attempting to replace them. Prevailing cultural and gender norms, access to technology, and differing perceptions of technology need to be taken into account when introducing digital tools.

Vietnam The Smart Village, Connected Commune initiative is a community of villages and communes in rural areas using digital platforms to improve lives of ethnic minoritie and isolated communities in the country.

The development of digital agriculture strategies helps ethnic minorities and mountainous, remote and isolated areas to improve agricultural and labour productivity , competitiveness and community welfare compared to more favourable regions. People and co-operatives in ethnic minority and mountainous areas have been trained on how to sell their products online, improve their sale skills and how to close applications. They are also being trained on how to pack and preserve agricultural products before sending them to distributors. Best practice for sustainable agriculture and farming is being shared between communities to minimise impacts of droughts, soil erosion and sea-level rise.

Source: Civil Service Modernisation in Asean Study Survey Response, Viet Nam, 2020.

Geographical Remoteness: In Southeast Asia, the geographical landscape varies significantly from archipelagos with thousands of distributed islands, such as Indonesia and the Philippines, to landlocked countries like Laos. For archipelagos, reaching remote islands is a significant challenge due to limited connectivity, both physical and digital, and difficult terrains, often leading to unequal access to D4Ag technologies and exacerbating the digital divide. Given the infrastructural and logistical barriers, scaling D4Ag solutions even within the country is challenging, often causing innovators to focus only on the largest islands. The challenging terrain of remote areas also often obstructs the delivery of training or support services for D4Ag tools, affecting their understanding, adoption, and utilization. The specific languages, needs, and contexts of different communities, enhancing their relevance and effectiveness.

On the other hand, the region's cultural, agricultural, and experiential diversity provide a unique conduit for knowledge exchange between the regions. Digital platforms can expedite this process, enabling farmers to learn from each other and disseminate innovative solutions and practices enhancing agricultural productivity and sustainability. Acknowledgment of the region's linguistic and cultural diversity can

potentially culminate in a robust, decentralized knowledge base and stimulate the development of bespoke D4Ag solutions.

Addressing these challenges requires investment in infrastructure, targeted training, and policies that ensure digital technology affordability and accessibility. D4Ag solutions designed with these issues in mind might need to incorporate offline functionalities or use alternative communication forms. Moreover, an active involvement of underrepresented groups and respect for the region's cultural, linguistic, and ethnic diversity should be at the heart of the design and implementation process.

HARNESSING D4AG TO SECURE SOUTHEAST ASIA'S RICE FUTURE

In Southeast Asia, agriculture—and particularly rice farming—plays a crucial role in the economy and food security. Rice is the single most important staple in the region, providing 50% of calorie intake for its population, and the region's rice areas comprise almost 30% of the world rice harvest.[75]

The region faces significant climate change threats, including rising temperatures, changing rainfall patterns, and an increase in extreme weather events, which pose significant risks to its rice agriculture. Digital technologies like remote sensing and geographic information systems (GIS) can assist in monitoring crop health, identifying pest and disease infestations, and managing irrigation, all crucial aspects in rice farming. Data-driven agronomy, backed by ML and AI, can provide personalized advice to farmers about the right variety of rice to grow, optimal planting times, and effective use of inputs.

The International Rice Research Institute (IRRI) has developed a set of digital tools specific for this crop. **IRRI's Rice Crop Manager (RCM)** enables extension workers to use a computer or smartphone to provide farmers with crop management recommendations matching their field conditions. RCM recommendations are provided to farmers through a one-page printout and SMS. According to IRRI, "use of RCM recommendations provided an average yield increase of 0.4 tons (400 kg) per crop per hectare equivalent to about US$100/ha/cropping season added net benefit in the Philippines.[76] IRRI offers a suite of many other digital tools, such as **EasyHarvest**—an Android mobile application that links farmers with machinery service providers in the Philippines, India, Cambodia, and Thailand; **WeRise**—a web-based data driven climate advisory (Laos, Indonesia, and the Philippines); a weed management tool called **WeedSmart; Rice Doctor,** an app-based disease diagnostics tool; and a digital extension service called **Rice Knowledge Bank**.

75 International Rice Research Institute
76 IRRI Crop Manager

Singapore-based **AgriG8** is integrating digital agriculture with financial services to empower smallholder rice farmers in Southeast Asia. The company is pioneering an innovative, agronomy-based risk assessment approach to bridge the gap between these farmers and financial institutions.

This approach involves predictive forecasts that only facilitate loan origination and credit assurance but also incorporate sustainability metrics. By doing so, it creates an opportunity for lenders to contribute positively to climate change mitigation.

For the farmers, AgriG8 offers a unique experience centred on enhancing their agricultural practices. The company provides tools and advice that can help farmers increase their yield and nutrient efficiency. At the same time, it aids them in reducing their carbon footprint and achieving sustainability certification.

Overall, AgriG8's approach aims to disrupt the destructive cycle of farmers simultaneously being victims of and contributors to climate change. By combining digital solutions, financial accesibility, and a strong focus on sustainability. AgriG8 is striving to build climate resilience among rice farmers in Southeast Asia.

FUTURE OUTLOOKS

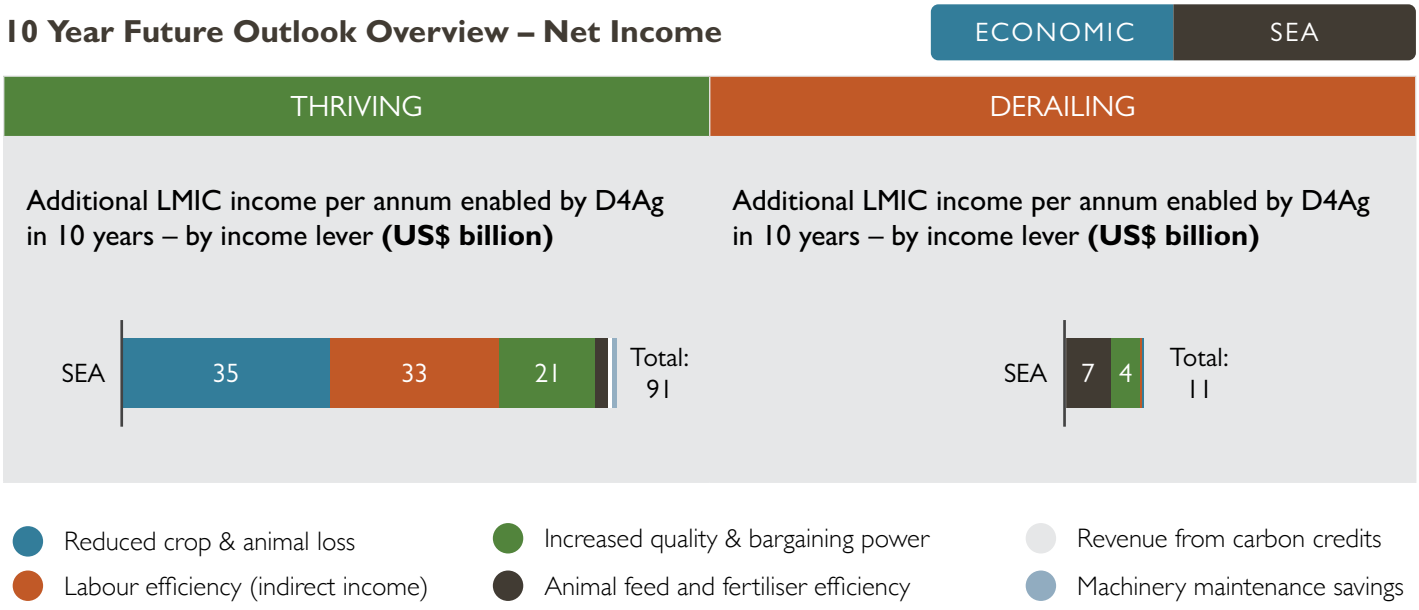
The unfolding decade presents both challenges and opportunities for the D4Ag sector. As the world grapples with rapid technological advances, climate change, and evolving socioeconomic dynamics, the D4Ag stands poised to play a transformative role, especially in LMICs. To capture this potential, we have meticulously analyzed and projected the future course of the sector and its impact across three impact vectors: economic, social, and environmental.

	Economic Projections (Additional LMIC income per annum enabled by D4Ag)	**Social Projections** (% of potential user base actively using D4Ag)	**Environmental Projections** (D4Ag-enabled farm-gate GHG change per annum)
Thriving Scenario	US$ 91 billion	35%	-78 CO2eq megatons
Derailing Scenario	US$ 11 billion	11%	+9 CO2eq megatons

Table 34. 10 Years' Outlook for the Sector: Southeast Asia

Economic Projections:

Southeast Asia may generate an additional income of US$91 billion from D4Ag in the next 10 years if conditions thrive predominantly from reduced crop and animal loss, improved labor efficiency, as well as increased quality and bargaining powers of produce in the region. However, the "derailing" scenario might see this number drop to less than 10% of the thriving potential.

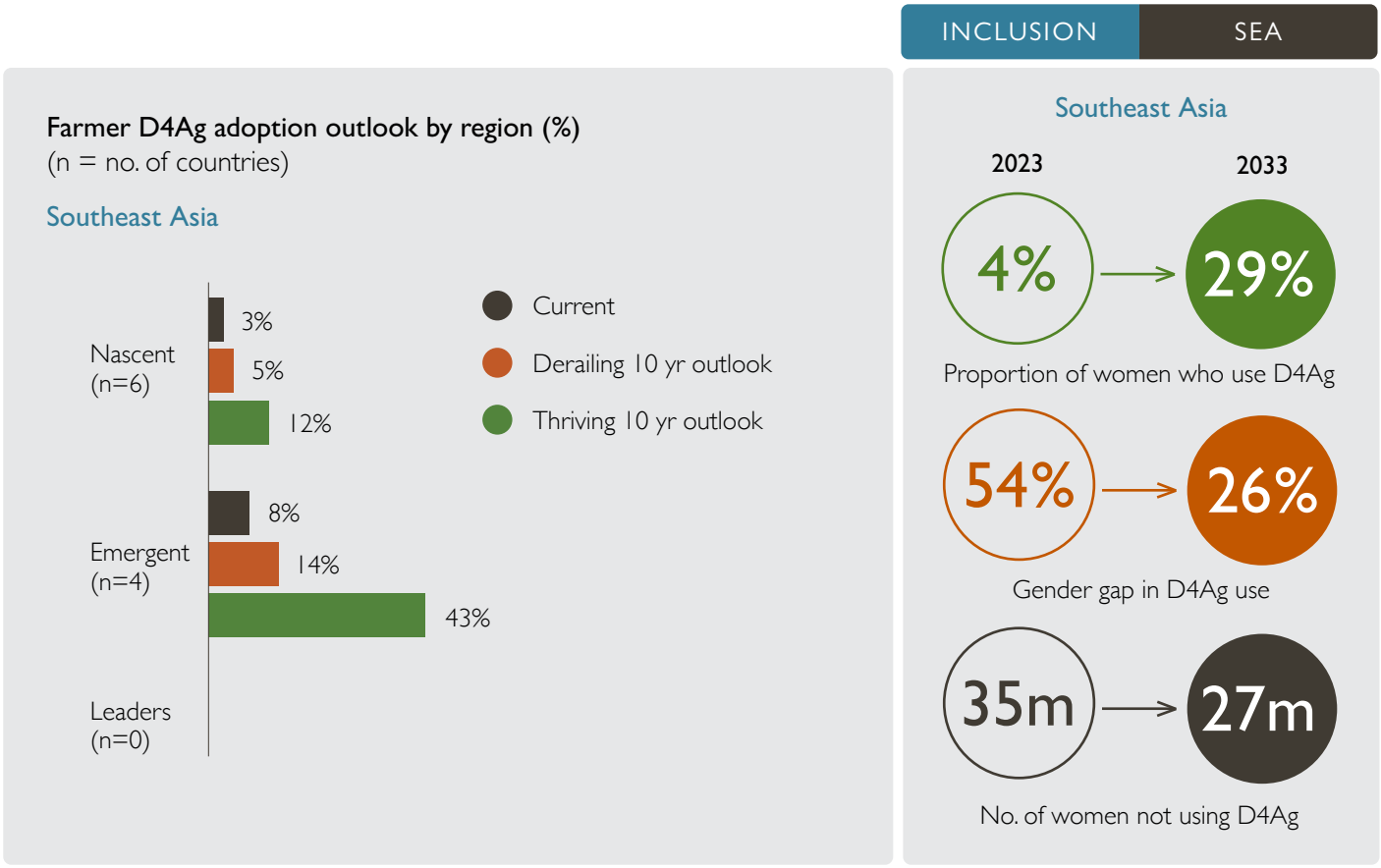


Source: USDA ERS International Agricultural Productivity indices, Beanstalk analysis

Figure 71. Economic Projections Southeast Asia

Social Projections:

D4Ag adoption, which averages 6% across Southeast Asia in 2023, may see varying levels in the future. Emerging champions in the region can see the adoption rates skyrocket up to 40%, while nascent countries are expected to see up to a 20% adoption rate. In the positive scenario, improving gender inclusivity could result in one in three females in agriculture adopting D4Ag tools, potentially halving the gender gap.



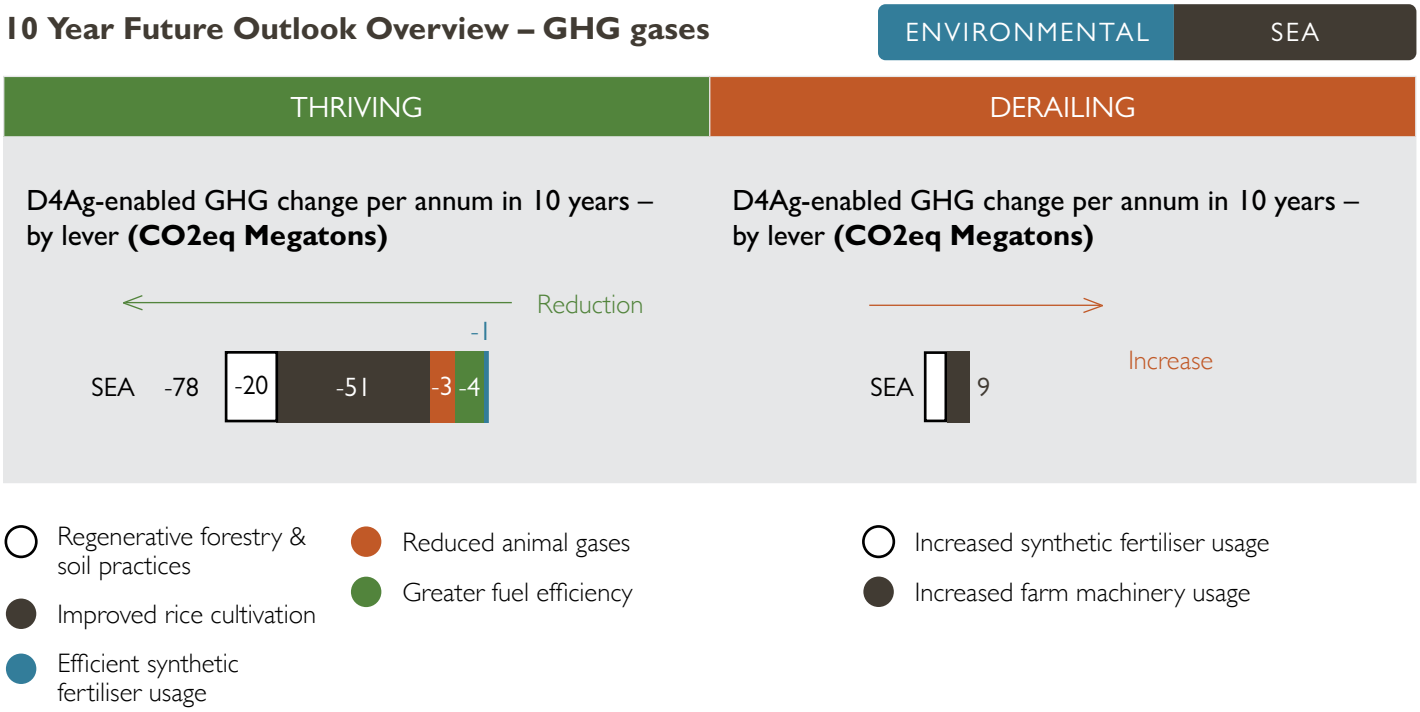
Note: Available data was extremely limited. Available country data was extrapolated to represent the entire progression status per region. Where data was not available, the 2016 Digital Adoption Index (DAI) was utilized to estimate current adoption levels. The thriving scenario was projected by using the internet adoption curves of each country with an adjustment factor. Relative to internet adoption, the following lag was assumed for D4Ag adoption: Leaders – 10-year lag, Emergent – 12-year lag, Nascent – 15-year lag.

Source: Various, World Bank World Development Indicators (Individuals using the Internet (% of population)), Beanstalk analysis

Figure 72. Social Projections Southeast Asia

Environmental Projections:

With a focus on rice farming, Southeast Asia, in a thriving scenario, might achieve a reduction of 78 megatons CO2eq annually, with 65% (51 megatons CO2eq) resulting from improved rice cultivation practices. In the negative scenario, increased use of farm machinery and synthetic fertilizer might lead to an increase in GHG emissions by 9 megatons CO2eq per annum.



Source: FAOSTAT domain Emissions Totals (last updated 22 May 2023), Beanstalk analysis

Figure 73. Environmental Projections Southeast Aisa

South Asia

ROLE OF AGRICULTURE AND SMALLHOLDER FARMERS IN SOUTH ASIA

Approximately 40% of South Asia's population are involved in agriculture; however, this number ranges widely from 62% in Nepal to 26% in Sri Lanka. Agriculture is also a significant contributor to the economies of South Asian countries, accounting for more than 20% of GDP in countries like Pakistan and Nepal. In India, the largest and the most populous country of the region, agriculture contributes to 16.6% of GDP and employs 44% of its total employed population. The role of agriculture in the region is the smallest in Sri Lanka: It contributes to less than 9% of GDP and to 26% of employment.

Smallholder farmers are vital to the economies and food security of the region: In India alone, despite owning only 33% of cultivated land, they produce more than 40% of food grains, and over half of its fruits, vegetables, oilseeds, and other crops.[18]

Agriculture Sector Contribution to GDP	Agriculture Sector Contribution to Sector Employment	Key Crops
16%[77]	41.32%[78]	Pulses, rice, wheat, sugarcane, groundnut, vegetables, fruit and cotton
Average Size of a Smallholder Farm	**Number of Smallholder Farmers**	**Share of Female Workers**
<2 ha	~180 m[79]	35%[80]

Table 35. Role of Agriculture in South Asia

77 World Bank Data, "Agriculture, forestry, and fishing, value added (% of GDP)", 2021
78 World Bank Data, "Employment in Agriculture (% of total employment)", 2021
79 Supply chains can't ignore 150 million small farmers, India needs a fair farm data standard - Solidaridad Network; IFAD – organizing smallholder farmers in Pakistan | Agribusiness Support Fund; iFarmer: The tech-enabled one-stop solution for smallholder farmers | The Daily Star; Nepali farmers diversify their income streams amidst climate crisis (unep.org); CSA in Sri Lanka
80 Asian Development Blog, 2015
81 Smallholder farmers in India: Food security and agricultural policy 2002/03 (fao.org)

D4AG REACH AND ADOPTION PROGRESS IN SOUTH ASIA

The D4Ag landscape in South Asia has been growing in the past five years, albeit at a slower pace than in 2012–2018, a trend observed globally. The region currently hosts around 288 active D4Ag solutions, with 35% of these launched after 2018. India clearly stands as the undisputable regional leader in the D4Ag domain, being home to approximately 90% of the D4Ag startups operating in South Asia.

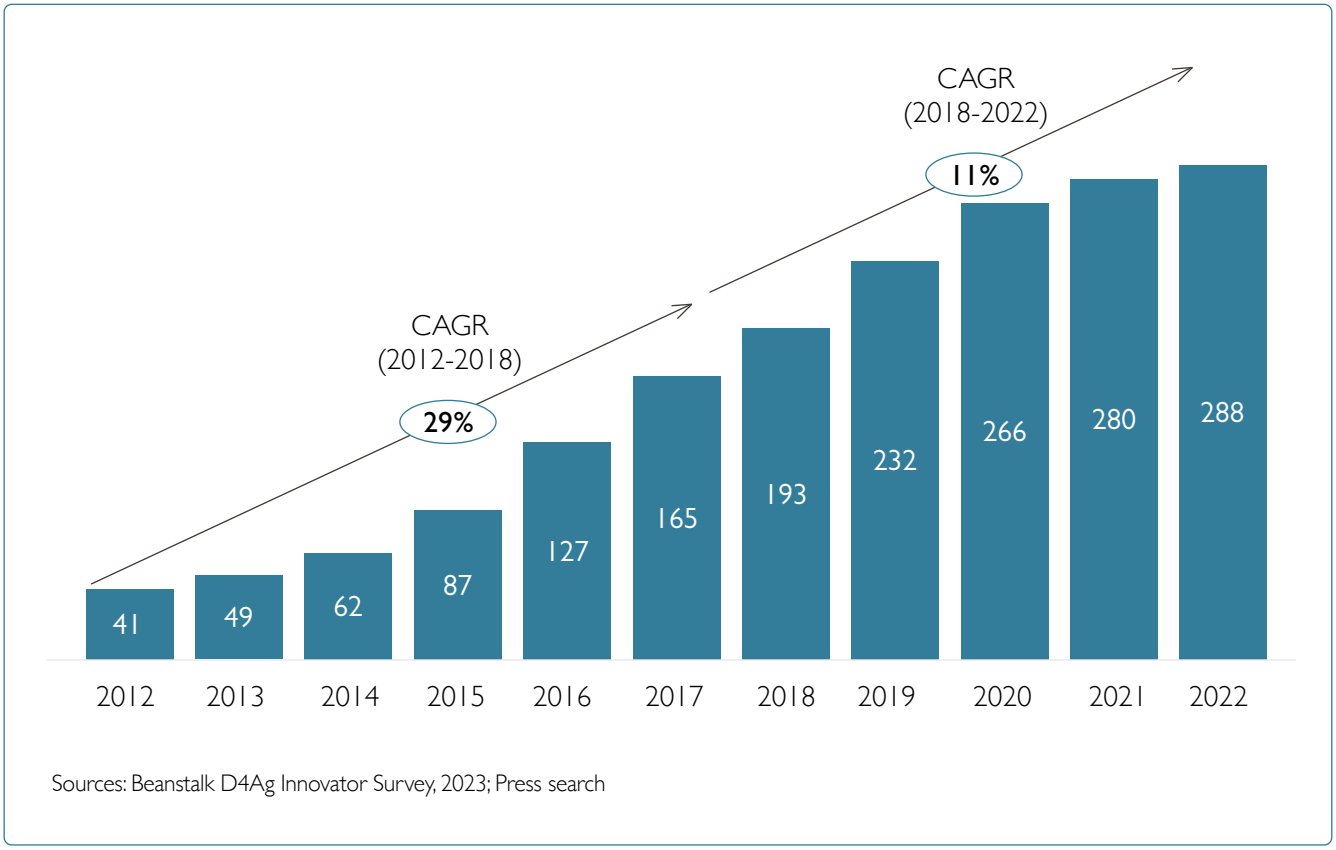


Figure 74. Number of Active D4Ag Solutions in South Asia, 2012-2022

Number of active D4Ag solutions (2022)	288
Number of active D4Ag solutions (2018)	193
Most commonly observed use case	Market Linkages & Access
Median number of users per solution	64,260
Proportion of innovators breaking even	52%

Table 36. D4Ag Reach and Adoption in South Asia.

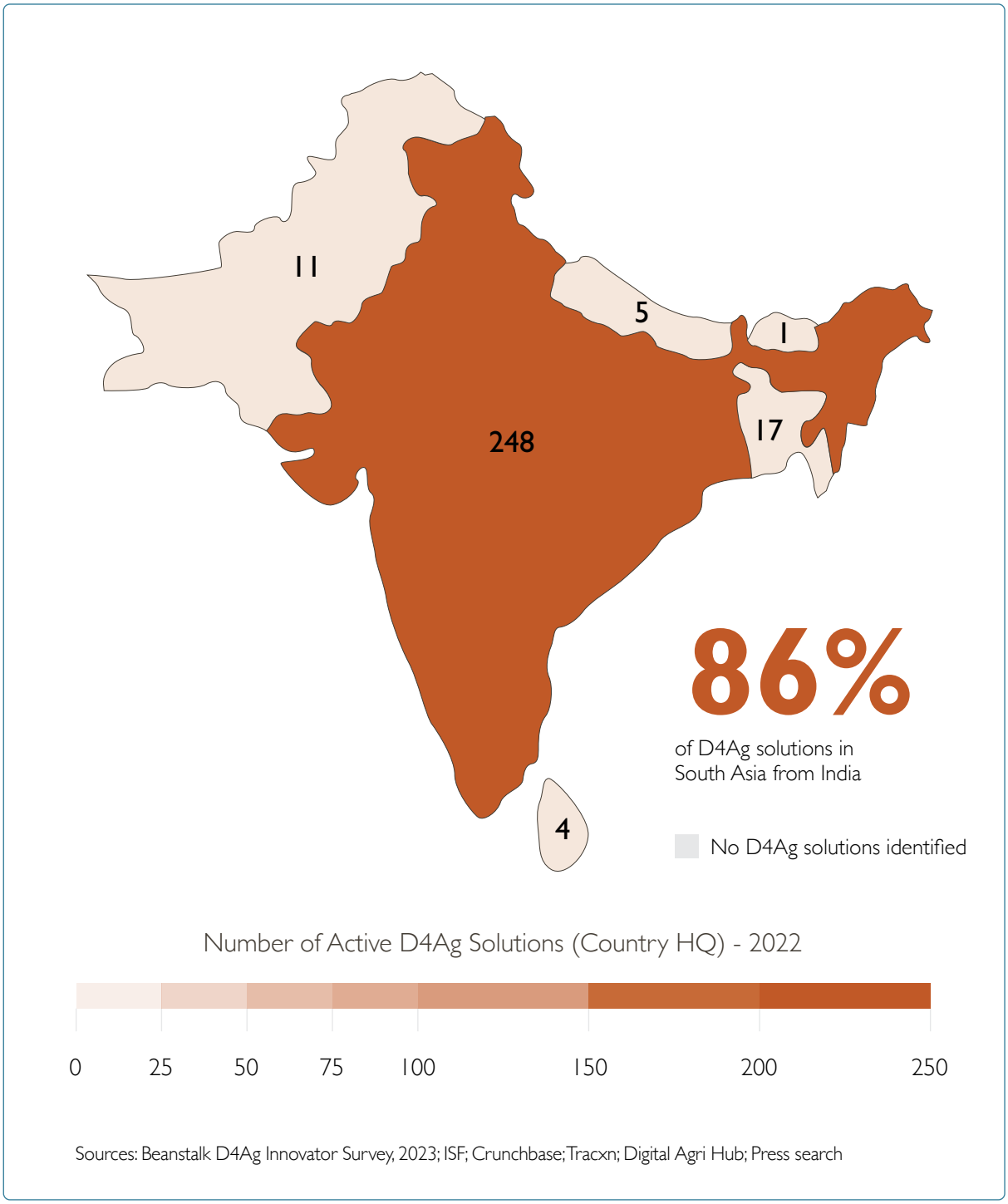


Figure 75. Number of Active D4Ag Solutions Per Country HQ, SA, 2022.

More than 40% of D4Ag solutions in South Asia now offer multiple use cases, indicative of the sector's maturation. Our interviews have supported this finding; early-stage companies initially focused on single product solutions but have since transitioned to network solutions that leverage digital platforms to achieve scalability across geographies. This shift in approach reflects the evolving dynamics of the D4Ag sector, where the emphasis has shifted from localized solutions to more extensive, interconnected platforms.

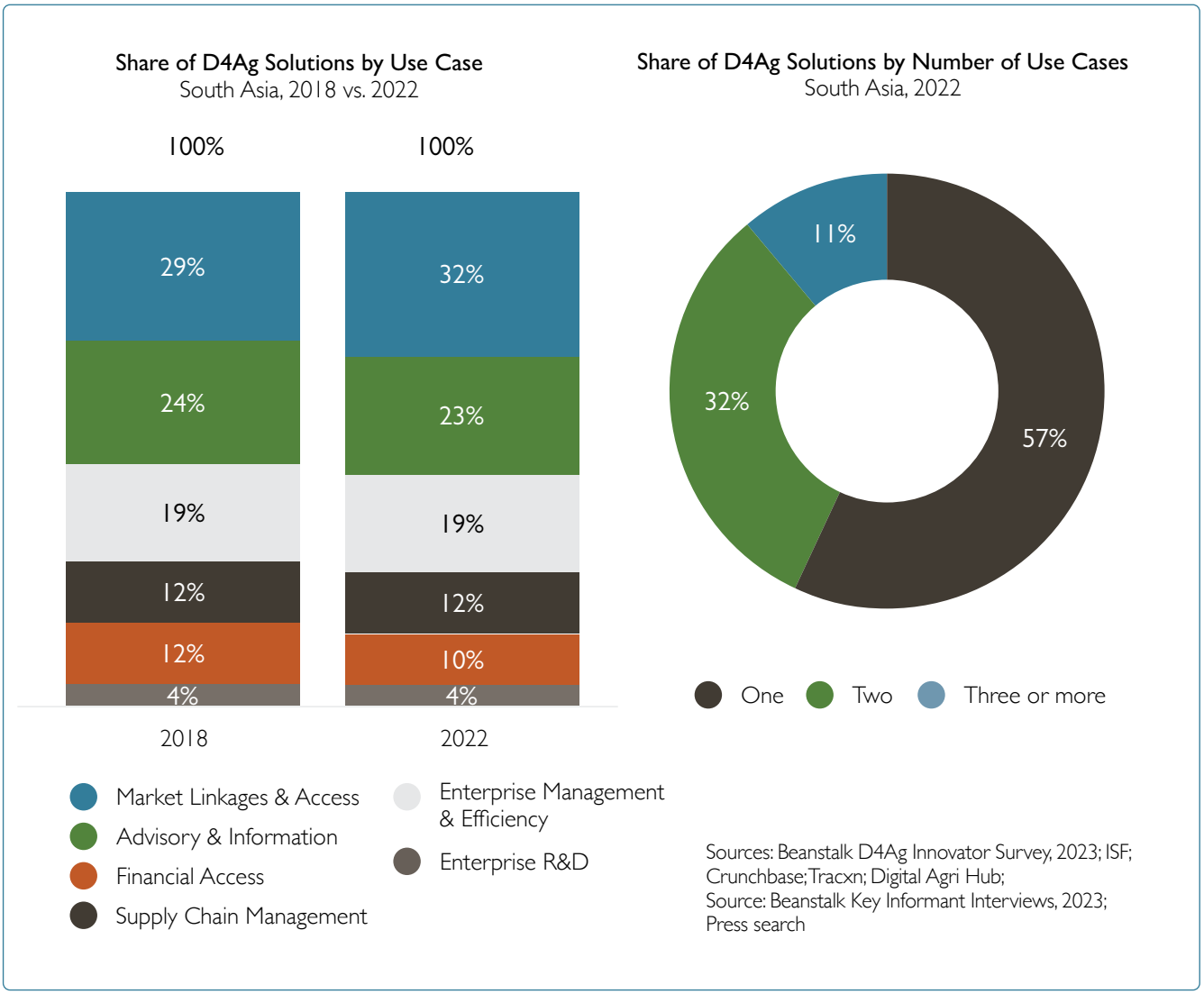


Figure 76. Current & Historical Mix of Use Cases across D4Ag Solutions (SA, % Of Total)

Indian D4Ag innovators have achieved remarkable scale, with **at least 11 solutions having more than two million registered users**, and the largest solution in India—**eNam** is now serving 17.5 million smallholder farmers, or about 15% of India's smallholder farming population. This significant user base underscores the potential and efficacy of these digital solutions in transforming the region's agricultural sector. Moreover, South Asian D4Ag innovators display a higher propensity toward profitability compared to their counterparts in Southeast Asia or Africa: In our interview sample, **60%** reported that they were currently breaking even.

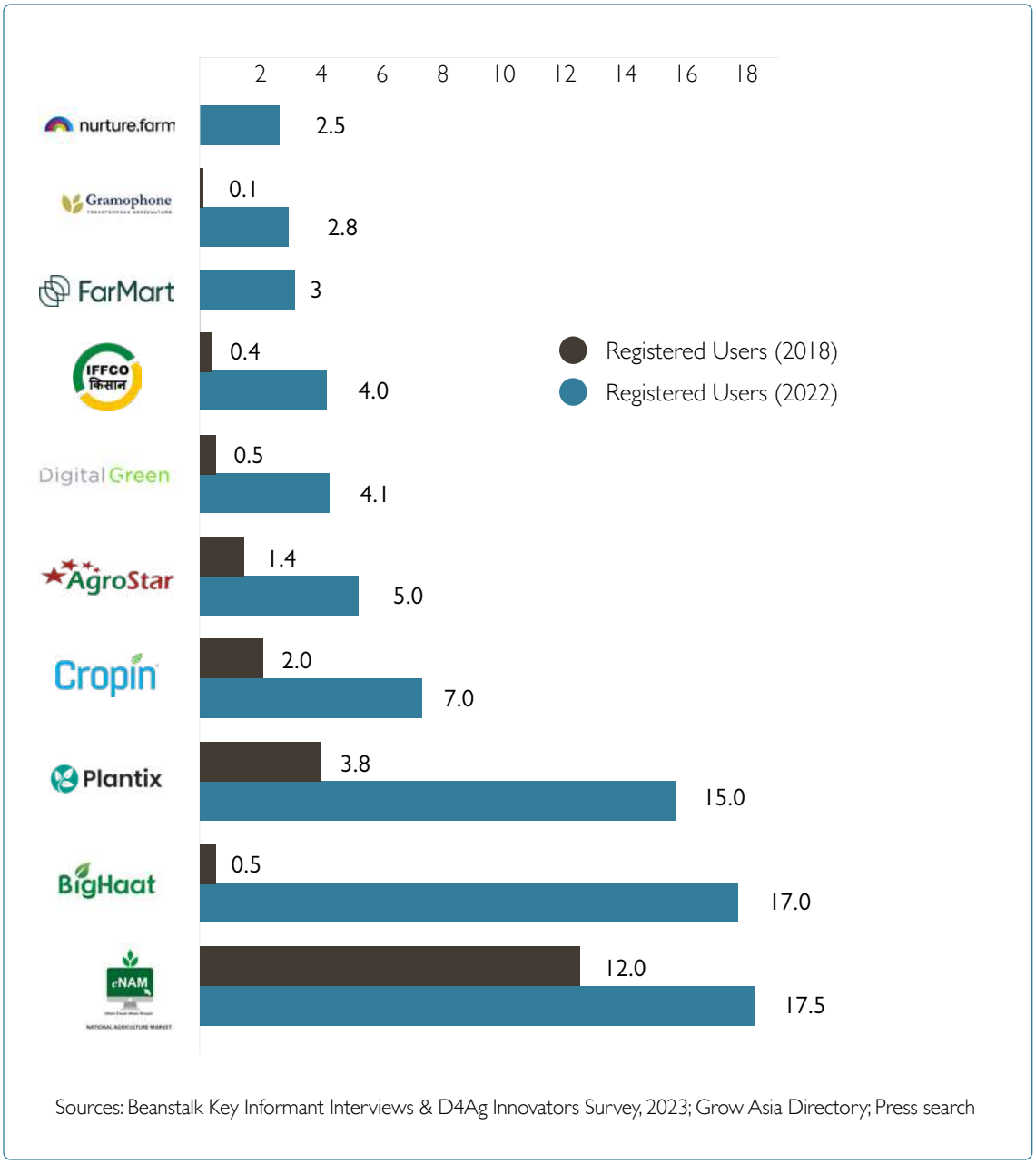


Figure 77. Registered Users of Top 10 D4Ag Solution Providers, SA

The investment landscape for D4Ag in South Asia is also maturing, with several standout innovators in India raising considerable capital from private investors, thereby reaching later stages of growth. **In 2022, Indian D4Ag innovators have raised an astonishing US$641 million in funding from private investors, double than their peers in all African countries together.** This indicates a growing investor interest in D4Ag solutions, acknowledging the sector's potential for high returns and significant social impact.

	Solution Name	Total Funding (US$, Mn)	Stage	HQ Country	Operations
1	Waycool	**$ 363.2**	Series D		
2	Ninjacart	**$ 333.2**	Series D		
3	DeHaat	**$ 254.3**	Series E		
4	Jumbotail	**$ 160.4**	Series C		
5	Captain Fresh	**$ 124.2**	Series C		
6	Arya.ag	**$ 113.2**	Series C		
7	AgroStar	**$ 112.4**	Series D		
8	Jai Kisan	**$ 95.7**	Series B		
9	ReshaMandi	**$ 54.2**	Series A		
10	FarMart	**$ 48.4**	Series B		

Table 37. Top 10 Solutions, by Total Amount of Private Funding Raised, 2022, SA, (US$, Mn). Source: Crunchbase

Despite India's dominance, other countries like Bangladesh, Pakistan and Nepal have also been making strides in this space, albeit at a slower pace. However, challenges like lower digital literacy, inadequate infrastructure, and limited access to capital are slowing down the pace of adoption.

There is an evident gap when it comes to technology sharing and transfer across countries in the region. Indian innovators, despite achieving significant scale and sophistication within the country, often do not expand their services to neighboring countries due to an already existing large total addressable market in their country, as well as a variety of challenges such as stark differences in digital infrastructure, literacy levels, agricultural practices, market dynamics, and regulatory environments. This absence of regional cooperation and technology sharing slows down the pace at which these innovations could otherwise disseminate and hampers the broader potential impact of D4Ag solutions in the region.

EMPOWERING SOUTH ASIAN WOMEN VIA D4AG

According to GSMA, **South Asian women are facing the largest digital divide in all LMICs: they are 41% less likely than men to use mobile internet, as compared to 36% in sub-Saharan Africa, and 2% in Latin America and Caribbean.** South Asian women are also experiencing the largest mobile and smartphone ownership gap (15% and 42%).[82] Female land ownership rates are also very low, ranging from 4.8% in Bangladesh to 12.8% in India, meaning that the vast majority of women farmers in South Asia are either unpaid family workers or paid laborers on others' farms.[83] Among the D4Ag startups we have interviewed, **the median share of female users stands at only 25%, versus 49% in sub-Saharan Africa**.

CLIMATE-SMART DIGITALIZATION OF SOUTH ASIAN LIVESTOCK

South Asia is an important center of livestock production: For example, meat production in India is estimated at 9.23 million tons in 2021–22 (~3% of the total meat production in the world) and is ranked fifth in the world in terms of production volume.[84] The nation also has the world's largest population of livestock at about 537 million.[85]

Digital technologies are increasingly being recognized as a powerful tool to enhance the resilience of livestock production in South Asia. These technologies offer new opportunities to address these challenges and drive productivity, efficiency, and sustainability in the livestock sector.

Digital Green

Digital Green: Empowering Women in Agriculture through Digital Solutions

Digital Green has been at the forefront of integrating gender perspectives into digital agricultural solutions since its inception. With over 75% of the farmers reached being women, Digital Green emphasizes strategies that amplify women's agency and promote an effective partnership between women and men to improve agricultural practices.

Video Content for Equality: Their video content shows both women and men as decision-makers, promoting joint decision-making and celebrating women as progressive farmers.

Technology for Inclusion: They use offline video and voice messaging to reach women farmer groups with limited literacy. For smartphone users, simplified app interfaces and voice-based interactions are designed.

Challenging Gender Norms: Digital Green supports the inclusion of women in agricultural leadership structures and work with governments to remove barriers to women's participation.

Prioritizing Gender Equality: The organization ensures gender sensitivity training for all staff and aims to diversify its leadership. Gender-focused policies and tools are integrated into their operations.

Resource Allocation: Digital Green advocates for and ensures the allocation of adequate resources to implement and expand their gender commitments.

82 GSMA Gender Gap, 2023
83 CIP, International Potato Center, 2020
84 Basic Animal Husbandry Statistics India, 2022
85 India National Dairy Development Board, 2019

Source: Upaj

Advisory & Information: Digital platforms are being used to deliver veterinary services and farmer education, overcoming geographical barriers and enhancing the reach of extension services. **The International Livestock Research Institute (ILRI)** has developed an Android-based **On-farm Feed Advisor** that helps extension staff to advise farmers on how to balance their animals' diet by matching nutrients and production in the feed offered, based on the animal body weight, milk production, and stage of pregnancy. The application selects the cheapest locally available feeds to bridge the nutritional gap. The results are given in the form of an advice memo with information including cost of feeding and additional income before and after balancing

Enterprise Management & Efficiency: Mobile applications are providing farmers with comprehensive livestock management solutions, including reproductive management, and health monitoring. Indian **Stellapps** has developed a wearable cattle tracker that detects heat and various disorders based on their activities and their resting behavior; and a herd management application, providing real time alerts on animal activities, personalized advisory, and cattle historical data management.

Market Linkages & Access: Digital platforms are linking livestock producers with markets, providing price information, facilitating online sales, and ensuring traceability along the value chain. Pakistan-based **Qurbani App** connects farmers and traders, allowing them to buy and sell livestock. Companies like Animall in India are leveraging digital technologies to integrate smallholder livestock farmers into formal value chains.

Financial Access: Bangladesh-based **iFarmer**, among other services, provides access to finance for smallholder farmers, including livestock producers, by developing risk assessment models in partnerships with banks and NBFIs. It has signed an MOU with a local insurance company to develop a livestock insurance product that could reduce vulnerability of the farmers of iFarmer.

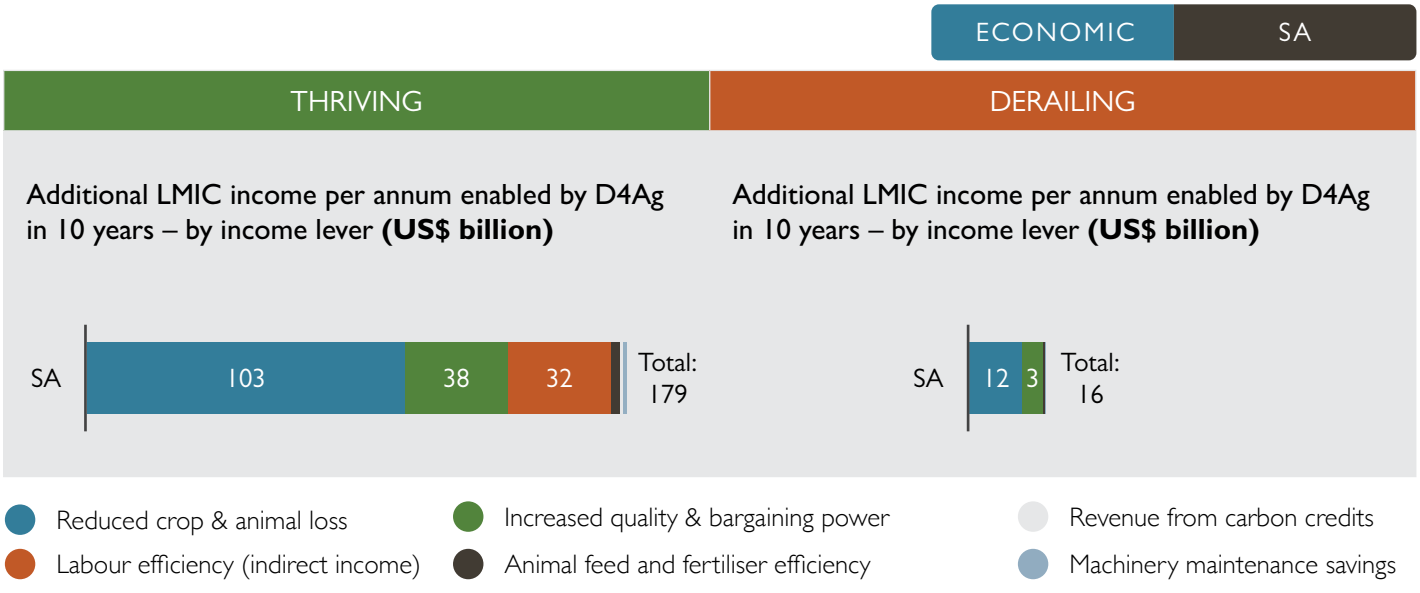
FUTURE OUTLOOKS

The unfolding decade presents both challenges and opportunities for the D4Ag sector. As the world grapples with rapid technological advances, climate change, and evolving socioeconomic dynamics, the D4Ag stands poised to play a transformative role, especially in LMICs. To capture this potential, we have meticulously analyzed and projected the future course of the sector and its impact across three impact vectors: economic, social, and environmental.

	Economic Projections (Additional LMIC income per annum enabled by D4Ag)	**Social Projections** (% of potential user base actively using D4Ag)	**Environmental Projections** (D4Ag-enabled farm-gate GHG change per annum)
Thriving Scenario	US$ 179 billion	50%	-149 CO2eq Megatons
Derailing Scenario	US$ 16 billion	21%	+9 CO2eq Megatons

Table 38. 10-Year Future Outlook for the Sector: South Asia

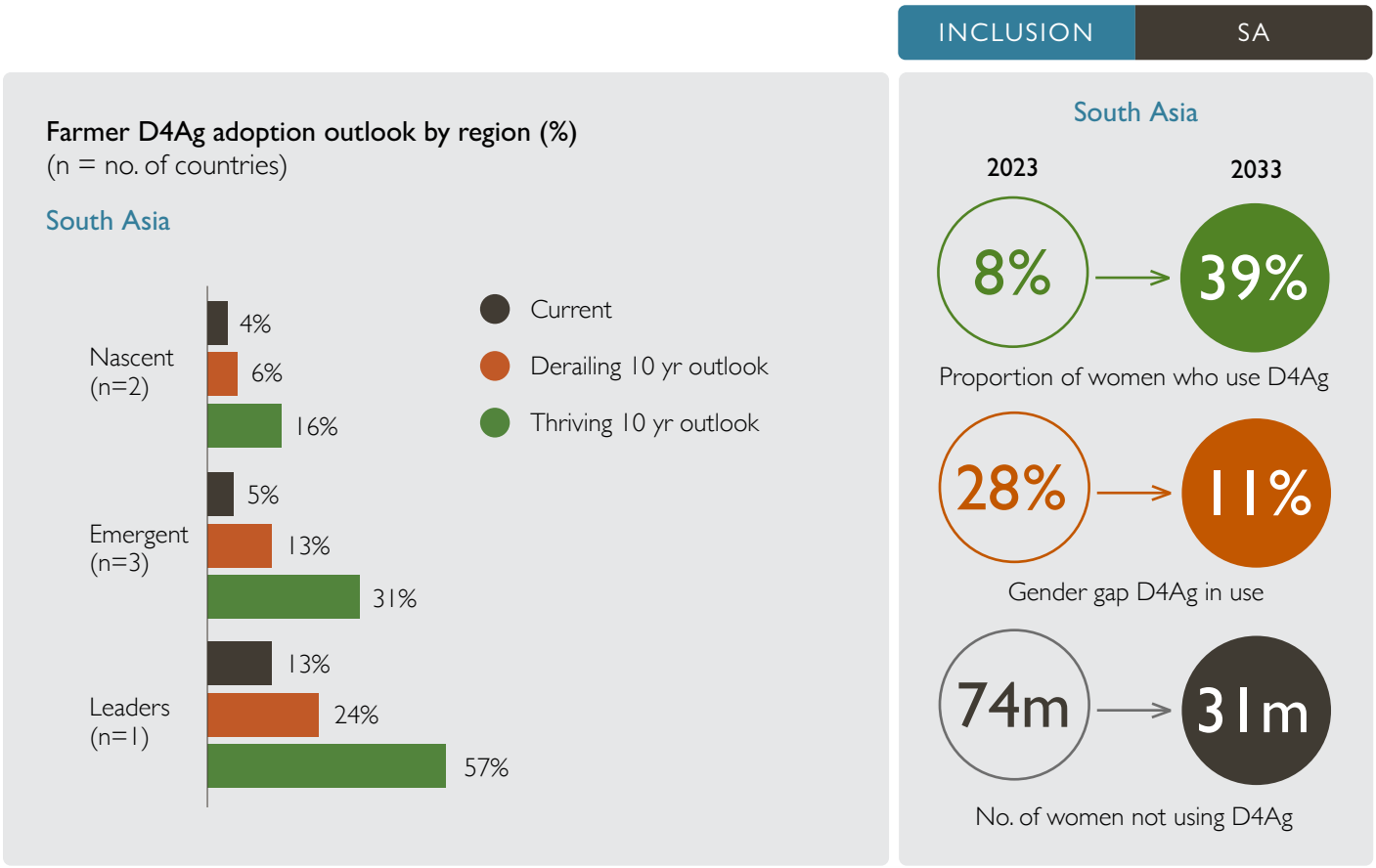
Economic Projections:
South Asia, with India as a key contributor, may see an additional income of US$ 179 billion if D4Ag thrives over the next decade, with reduced crop and animal loss contributing more than half of this growth. However, in the negative scenario, this figure could plummet to just 10% of the potential.



Source: USDA ERS International Agricultural Productivity indices, Beanstalk analysis

Figure 78. Economic Projections South Asia

Social Projections:
With an average D4Ag adoption rate of 10% across the region in 2023, in 10 years' time, India as a leader of D4Ag innovation in the region could experience an adoption rate of 57%, under thriving conditions. Nascent countries in the region might also see up to 20% of their farmers adopting D4Ag solutions. Moreover, the female agricultural workforce could significantly benefit, **with four out of 10 women adopting D4Ag tools and reducing the gender gap by 60%**.

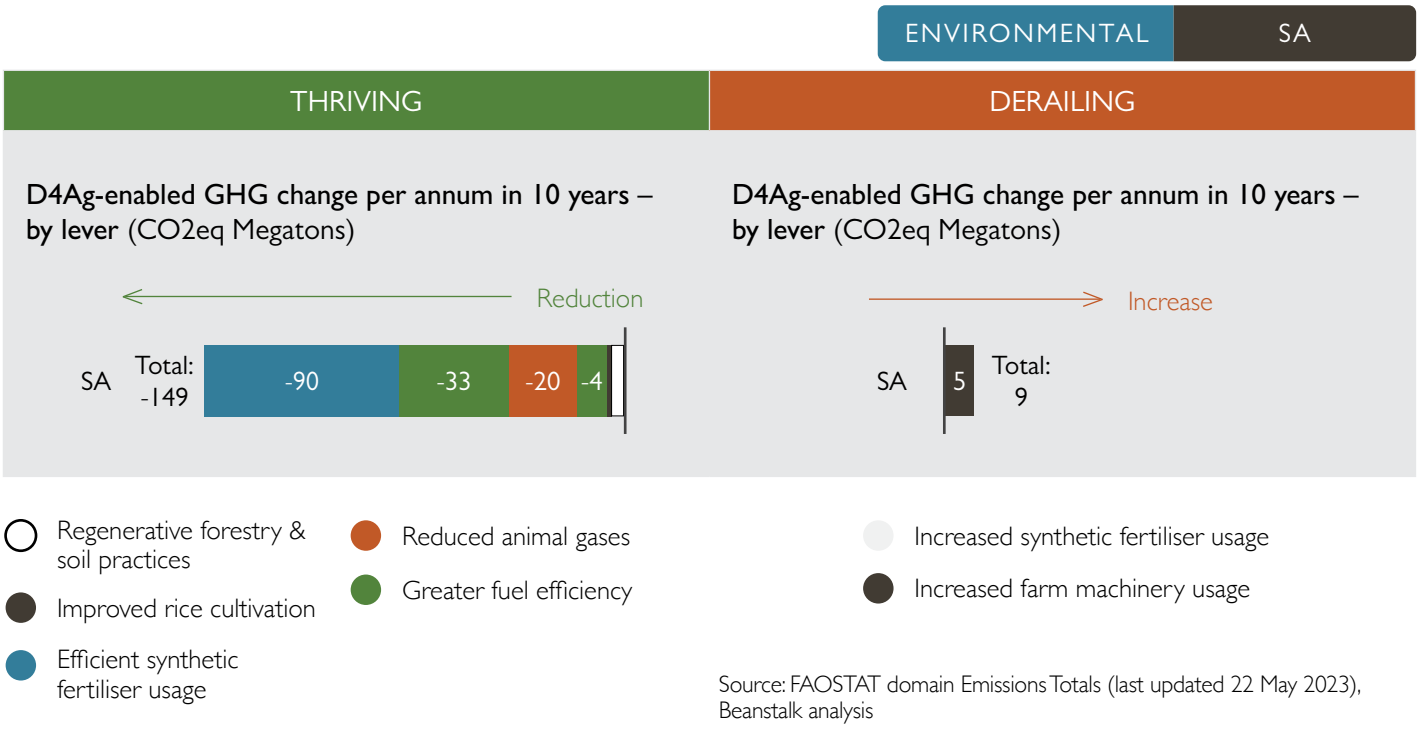


Note: Available data was extremely limited. Available country data was extrapolated to represent the entire progression status per region. Where data was not available, the 2016 Digital Adoption Index (DAI) was utilized to estimate current adoption levels. The thriving scenario was projected by using the internet adoption curves of each country with an adjustment factor. Relative to internet adoption, the following lag was assumed for D4Ag adoption: Leaders – 10-year lag, Emergent – 12-year lag, Nascent – 15-year lag.

Source: Various, World Bank World Development Indicators (Individuals using the Internet (% of population)), Beanstalk analysis

Figure 79. Social Projections South Asia

Environmental Projections:
South Asia could lead with the highest reduction in GHG emissions across LMICs (-149 megatons CO2eq) under a thriving scenario, mainly driven by improving regenerative forestry and soil practices decreasing emissions by 90 megatons CO2eq per annum. Improved rice cultivation practices is also a crucial driver of decreasing emissions in the future: We estimate that it has a potential to bring GHG emissions by 33 megatons CO2eq per annum. However, if the potential of D4Ag is not fully realized, we might see a worrying trend toward increased emissions in the sector by 9 megatons CO2eq, annually.



Source: FAOSTAT domain Emissions Totals (last updated 22 May 2023), Beanstalk analysis

Figure 80. Environmental Projections South Asia

Latin America and the Caribbean

ROLE OF AGRICULTURE AND SMALLHOLDER FARMERS IN LATIN AMERICA AND THE CARIBBEAN

Latin America and the Caribbean countries, abundant with natural resources, including a third of the world's freshwater resources and high-quality agricultural soil, vary significantly in the structure and scale of their agricultural sectors. The region's GDP contribution from the agriculture, forestry, and fishing sector stands at 6.9%, with country-specific percentages ranging from under 3% in the Caribbean countries like Trinidad and Tobago, St. Lucia, and Panama to over 10% in Honduras, Haiti, Nicaragua, and Bolivia.

The agriculture sector in the LAC region is a crucial employment source, engaging 15.0% of the region's labor force. In countries like Haiti, Ecuador, Bolivia, Guatemala, and Nicaragua, the labor force engaged in agriculture approaches one-third, mostly comprising smallholder farmers working on labor-intensive crops. However, in Southern Cone countries where agriculture is highly mechanized, this percentage drops below 10%. The World Bank estimates that the LAC region hosts 13 million smallholder farms out of a total 15 million farms in the region.[86] The agricultural sector in LAC holds great potential, often touted as the "next global breadbasket,"[87] but it will require significant productivity gains, especially in smallholder farming.

86 Virginia Tech: GAP report, 2021
87 IDB & Global Harvest: The Next Global Breadbasket, How Latin America Can Feed the World, 2014

Agriculture Sector Contribution to GDP	Agriculture Sector Contribution to Sector Employment	Key Crops
6.9%[88]	15%[89]	Corn, soybean, sugarcane, wheat, coffee, beans
Average Size of a Smallholder Farm	**Number of Smallholder Farmers**	**Share of Female Workers**
2.5 ha (1.3 ha in the Caribbean)[90]	~15m[91]	>30%

Table 39. Role of Agriculture in Latin America and the Caribbean

Number of active D4Ag solutions (2022)	240
Number of active D4Ag solutions (2018)	200
Most commonly observed use case	Enterprise Management & Efficiency
Median number of users per solution	40,000
Proportion of innovators breaking even	67%

Table 40. D4Ag Reach and Adoption in LAC

D4AG REACH AND ADOPTION PROGRESS IN LAC

A total of 240 D4Ag tools have been identified in the region, with over 80% of these concentrated in just three countries: Brazil, Argentina, and Colombia. Brazil has emerged as a regional leader in D4Ag innovation, accounting for more than 60% of all identified solutions in the region.

88 World Bank Data, "Agriculture, forestry, and fishing, value added (% of GDP)", 2021
89 World Bank Data, "Employment in Agriculture (% of total employment)", 2021
90 ECLAC, FAO and IICA (2019), The Outlook for Agriculture and Rural Development in the Americas: 2019–2020
91 Home | OECD iLibrary (oecd-ilibrary.org)

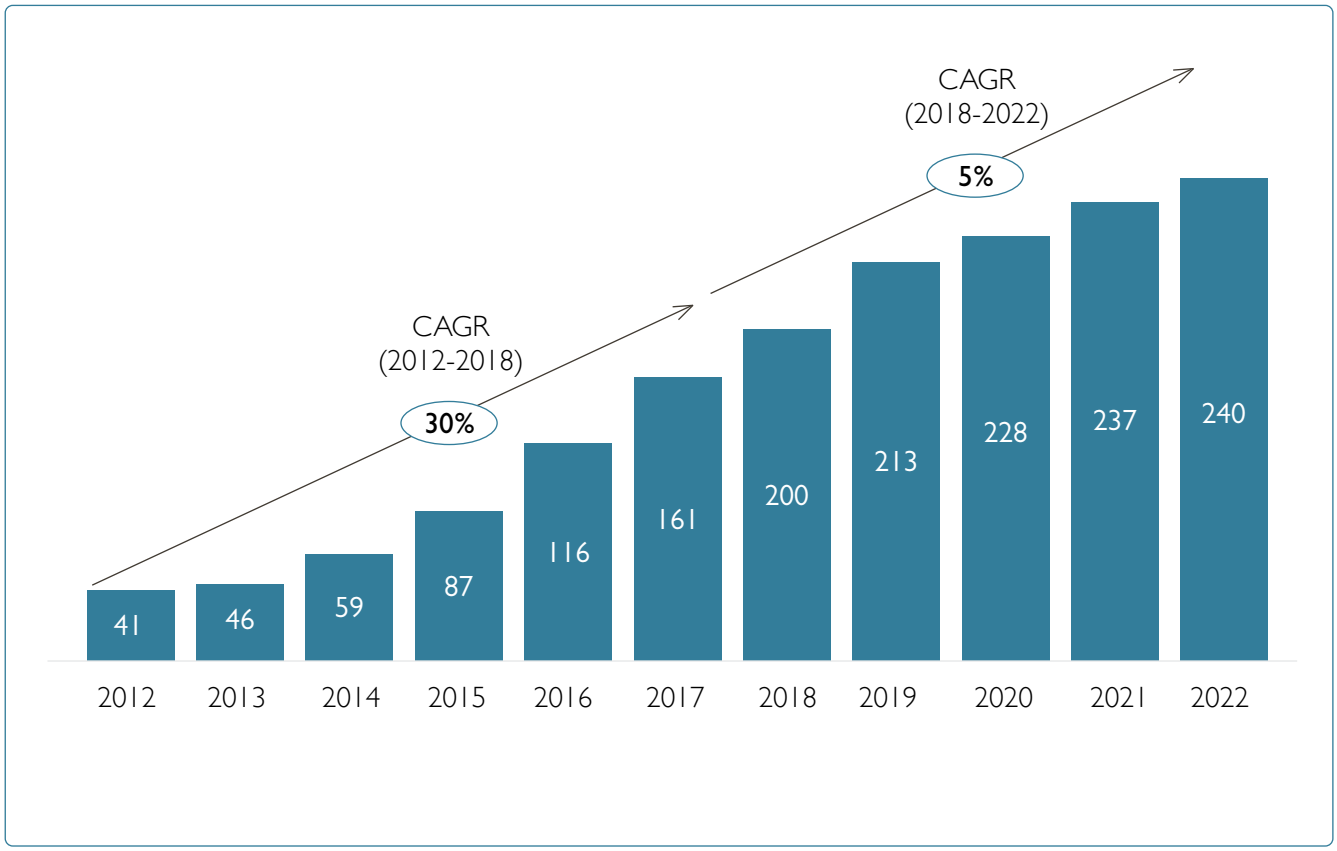


Figure 81. Number of Active D4Ag Solutions in LAC, 2012-2022

Latin American D4Ag solutions also tend to have a 20%–50% smaller user base size than their peers in Africa or Asia. This is in part due to the smaller addressable market in the region, as well as the fact that D4Ag innovators in Latin America tend to focus more on larger-scale commercial farmers than on smallholders. As a result, few digital tools have managed to exceed 25,000 registered users, with most having less than 10,000 registrants. Interestingly, **the**

Source Source: Feed the Future Flickr. Photo credit: Patrick Meinhardt for Catholic Relief Services

Figure 82. Number of Active D4ag Solutions, by Country HQ, 2022.

proportion of innovators breaking even is 67%, higher than the global average. This promising finding can be attributed to a few key factors. One significant contributor is the presence of larger, more tech-intensive farms in regions like Brazil and Argentina. These larger farms typically have greater capacity to invest in and benefit from D4Ag solutions due to their scale of operations; and their readiness and willingness to pay for these technologies

can help drive revenue for D4Ag innovators, aiding their journey to financial breakeven. Furthermore, the strategic orientation of D4Ag innovators toward business-to-business (B2B) solutions, such as supply chain management, could also be playing a role. B2B solutions often cater to larger organizations with deeper pockets compared to individual smallholder farmers, enabling them to command higher price points and generate more stable revenue streams. This focus on more lucrative B2B markets can significantly contribute to the higher breakeven rate observed among these D4Ag innovators.

The most commonly observed use case in the Latin American D4Ag landscape is "Enterprise Management & Efficiency," which contrasts with the "Market Linkages & Advisory Services" that dominate the markets in Africa and Asia, likely reflecting a dominant role of large corporate agribusinesses in the region.

The D4Ag sector in the region showcases diverse levels of development, with certain countries like Brazil standing out as leaders in D4Ag. Interestingly, two-thirds of innovators

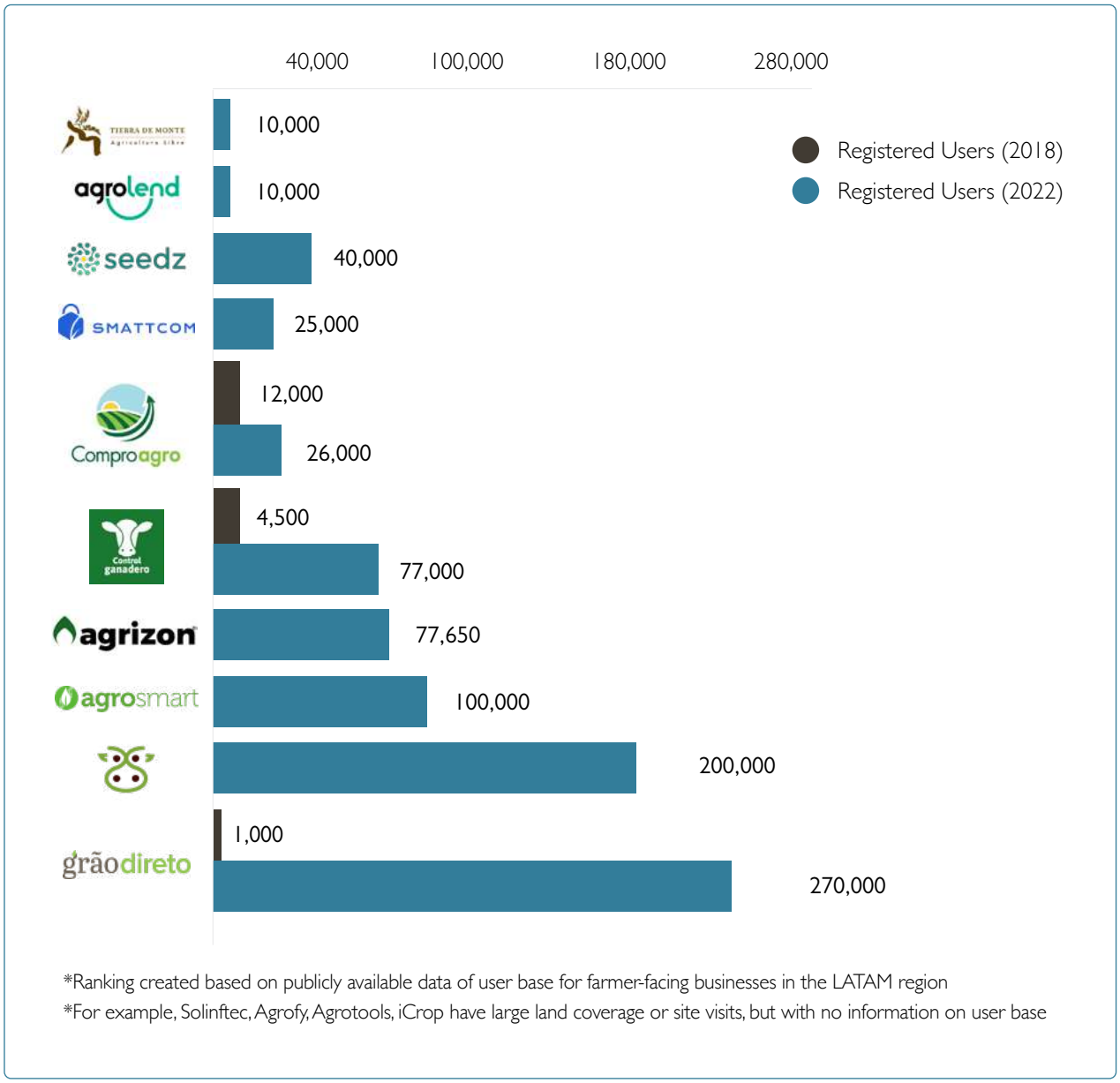


Figure 83. Registered Users of Top-10 D4Ag Solutions. LAC, 2022

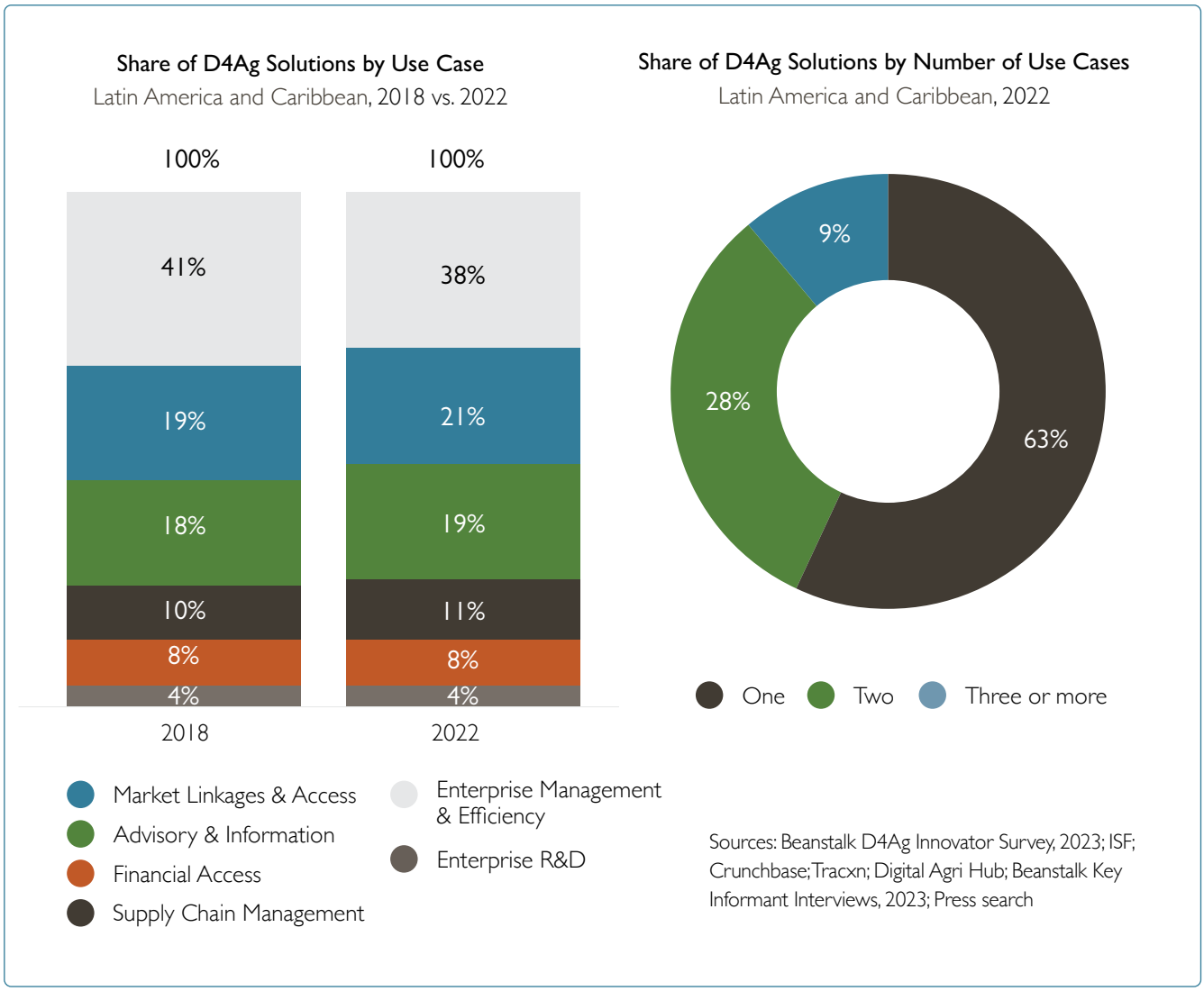


Figure 84. Current & Historical Mix of Use Cases (LAC, % Of Total)

in the region are focusing on "point-solutions," instead of offering various services, reflecting a targeted approach to solving specific problems faced by rural producers. These tailored solutions, especially in the area of "Enterprise Management & Efficiency," are often driven by various factors such as accessibility to extensive rural production data, investment preferences of venture capitalists, scalable technology, and alignment with the key pain points identified by rural producers in the region. The nuanced landscape, therefore, illustrates a region that is not only embracing innovation in agribusiness but also shaping it according to unique needs and opportunities.

In 2022, Latin American D4Ag innovators raised US$613 million in total funding. However, significant investment in the D4Ag sector in Latin America has been limited to a few selected innovators. Notably, eight out of 10 largest investment rounds are concentrated in Brazil, again demonstrating the country's leading role in the region's D4Ag development.

	Solution Name	Total Funding (US$,Mn)	Stage	HQ Country	Operations
1	Frubana	**$ 271.1**	Series C		
2	Solinftec	**$ 146.6**	Series C		
3	Agrolend	**$ 106.8**	Series B		
4	Agrofy	**$ 60**	Series C		+7
5	TerraMagna	**$ 42.7**	Series A		
6	Agrotools	**$ 21**	Series B		+6
7	Seedz	**$ 16.5**	Series A		
8	Agrosmart	**$ 15.5**	Series A		
9	Grão Direto	**$ 14.3**	Series A		
10	Rúmina	**$ 5.5**	Series A		

Table 41. Top 10 Solutions by Total Amount of Private Funding Raised, 2022, LAC, (US$, Mn). Source: Crunchbase.

ROLE OF D4AG IN NAVIGATING LAND RIGHTS IN LATIN AMERICA AND THE CARIBBEAN:

Latin America and the Caribbean face widespread land tenure insecurity, a high number of informal property holders, and insecure land rights for women and indigenous communities. These issues are intensified by outdated, complex land administration systems and disorganized property data, and further complications arise from inadequate land risk assessment resources, poor implementation of existing laws, and a lack of legal frameworks to pursue reforms.[92]

1. Land Ownership Disparities:

Historic and systemic issues have resulted in a severe concentration of land ownership in the region, leaving women, indigenous people, and other marginalized groups with smaller, fragmented, or informally held lands. According to FAO, LAC is the region with the most unequal land distribution in the world.[93] Moreover, according to Oxfam, the one percent of the largest estates account for more than half of the region's agricultural land; conversely, 80% of the smallest farms occupy less than 13% of productive land.[94]

92 IFAD's support for land and natural resource tenure security. Latin America and the Caribbean. IFAD, 2018
93 Land governance in Latin America and the Caribbean. Innovation and inclusion for economic recovery and resilience. FAO, 2022
94 Oxfam. 2016. Unearthed: land, power and inequality in Latin America.

Papyrus, an organization active in Haiti, has made strides in the digital agriculture sector through the creation of a mobile application designed to assist farmers. The app allows comprehensive tracking of farming processes, from field preparation to the distribution of crops at facilities. It records real-time data from the field and aids in crop monitoring. This wealth of data can not only optimize farming practices but also, unexpectedly, has the potential to address contentious land rights issues in the region.

A few years ago, Papyrus became aware of a significant challenge facing many Haitian farmers: insecure land tenure. Due to the absence of a clear cadastral system, disputes over land ownership are commonplace. The organization realized that the extensive data it had been gathering for approximately eight years could potentially serve as evidence of farmers' land use, helping to clarify land rights issues.

The data can provide a history of farmers interaction with their land, which, in turn, could be instrumental in aiding farmers in obtaining legal papers and titles to their land. This unexpected use case underlines the importance and potential of the data collected by Papyrus.

The realization of this additional function of the data has placed a new responsibility on the organization, leading them to question how the data can best be utilized to serve the interests of the farmers they work with. This revelation has underscored the need for a more reflective approach on how data collection can be tailored to better serve and benefit the farmers themselves.

Papyrus now carries the burden of this responsibility, recognizing the importance of the historical data they hold about farmers and their farms. The challenge ahead is to figure out the best way to leverage this data, not only to enhance agricultural practices but also to secure farmers' land rights, a vital component in improving their livelihoods and fostering agricultural development.

As one in five people in LAC feel insecure in their rights over their housing and land, these farmers are often discouraged from investing in long-term agricultural improvements, including implementation of D4Ag solutions.[95] Moreover, many digital solutions in agriculture rely on formal land titles or registration to validate and recognize farmers, and when land rights are informal or unrecognized, these farmers are often left out of such digital programs.

2. Access to Legal Rights and Services:

Many of these disadvantaged groups lack access to legal resources and services to help them secure their land rights formally. Their limited familiarity with legal procedures, language barriers, and geographic isolation further complicate this issue. This reduces their ability to protect their land rights and undermines their confidence in leveraging land assets for agricultural development.

3. Cultural and Gender Norms:

In many Latin American societies, the longstanding legacies from the era of colonization continue to influence land inheritance and ownership. These historical patterns often disadvantage women and indigenous communities, who still face challenges in fully engaging with and benefiting from the agricultural sector, including the adoption of D4Ag tools.

4. Lack of Representation:

The underrepresentation of disadvantaged groups in policymaking and decision-making processes related to land and agriculture often results in policies that do not consider their needs and constraints, including their ability to adopt and benefit from D4Ag solutions.

95 PRINDEX. 2020. Comparative Report: A global assessment of perceived tenure security from 140 countries.

BATTLING DEFORESTATION IN LATIN AMERICA: THE ROLE OF D4AG

Despite the latest strides, deforestation is still a critical concern in Latin America, where the conversion of forests to agricultural land threatens biodiversity, contributes to climate change, and impacts indigenous communities. The Natural Resources Defense Council (NRDC) estimates that deforestation affects between 27% and 43% of land in countries like Peru, Bolivia, Chile, and Ecuador. Soil degradation, another serious issue, results from both deforestation and overgrazing, with erosion impacting more than 68% of South America's soil. Water pollution and scarcity, as evidenced by Chile's 13-year megadrought, further exacerbate these environmental challenges.[96]

Various countries have made significant strides by implementing rigorous monitoring systems, promoting sustainable land-use practices and fostering international partnerships for conservation. Digital agriculture tools have emerged as powerful allies in the fight against deforestation, assisting farmers in improving agricultural practices, optimizing land use, and conserving forests. These tools often leverage advances in satellite imagery, remote sensing, and machine learning to provide timely, accurate data.

CARBONEXT NATURE & FUTURE

Carbonnext is actively conserving over 1.6 million hectares of the Amazon Rainforest. Its strategy involves monitoring and preserving forest land and selling carbon credits, serving a dual purpose of conservation and sustainable economic activity. Through this model, Carbonnext not only preserves the forest but also contributes to the global fight against climate change by providing a way for other entities to offset their carbon emissions.

re.green

Re.green is a conservation-focused startup that employs spatial analysis technology along with partnerships with local communities to restore and monitor forests. It recently acquired Bioflora, a tree nursery, enhancing its capacity to plant up to two million seedlings annually with potential expansion to plant up to 10 million seedlings per year. Re.green is an innovative solution blending technology and community collaboration to drive reforestation efforts.

MOMBAK

Mombak is a startup that either purchases or leases deforested lands and restores biodiversity to them. Its unique approach ensures the reforestation of depleted lands while promoting biodiversity. Additionally, Mombak places significant emphasis on restoring and protecting local surrounding communities, demonstrating a holistic approach to environmental and social sustainability.

MOSS

Moss operates an online carbon credits platform. Its mission is to help companies offset their carbon emissions, and it does so by providing a marketplace for the trade of carbon credits. By facilitating these transactions, Moss allows for financial incentives in the pursuit of reducing global carbon emissions, thus contributing to the broader climate change mitigation efforts.

Table 42. Examples of Climate-Smart D4Ag Tools in LAC

96 Data snapshot: Meet the startups tackling conservation and deforestation in Latin America. AgFunder, July, 2023

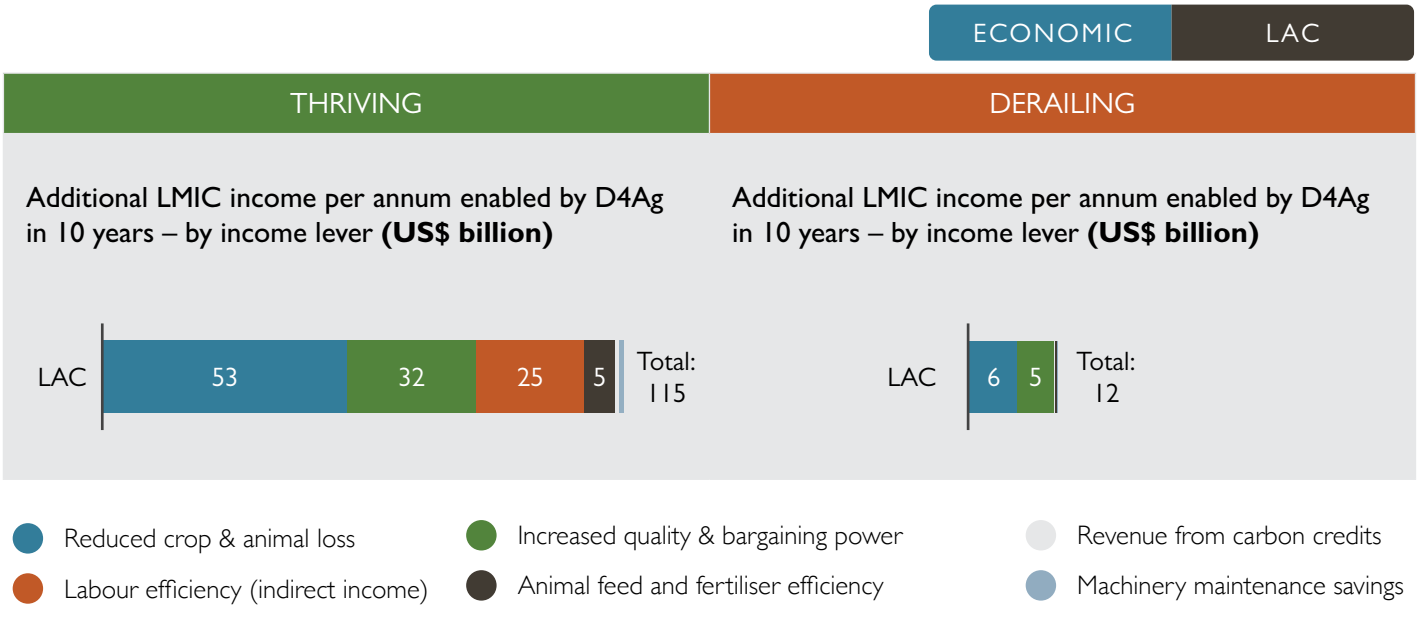
FUTURE OUTLOOKS

The unfolding decade presents both challenges and opportunities for the D4Ag sector. As the world grapples with rapid technological advances, climate change, and evolving socioeconomic dynamics, the D4Ag stands poised to play a transformative role, especially in LMICs. To capture this potential, we have meticulously analyzed and projected the future course of the sector and its impact across three impact vectors: economic, social, and environmental.

	Economic Projections (Additional LMIC income per annum enabled by D4Ag)	**Social Projections** (% of potential user base actively using D4Ag)	**Environmental Projections** (D4Ag-enabled farm-gate GHG change per annum)
Thriving Scenario	US$ 115 billion	36%	-72 CO2eq megatons
Derailing Scenario	US$ 12 billion	24%	+52 CO2eq megatons

Table 43. 10 Years' Outlook for the Sector: Latin America and the Caribbean

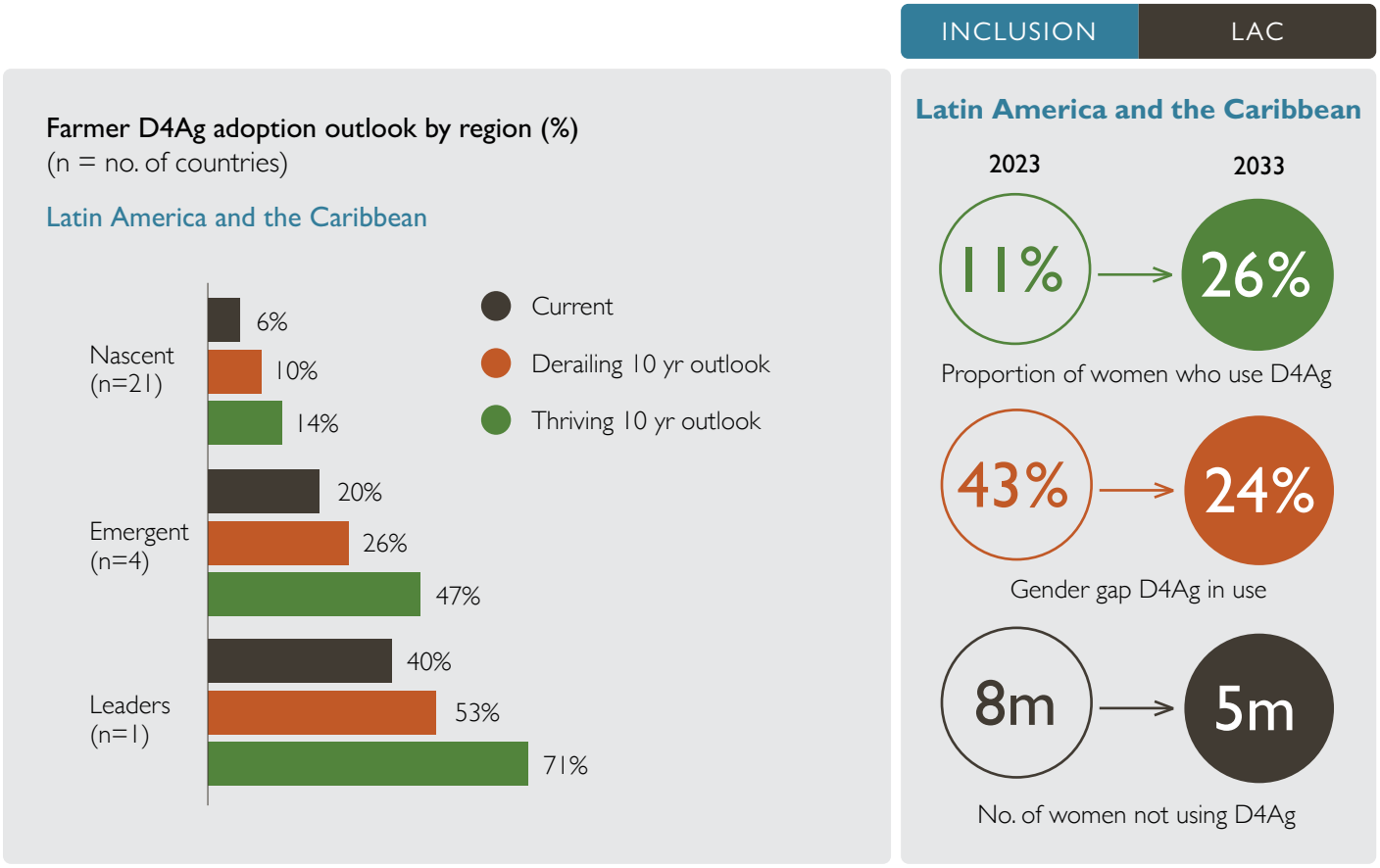
Economic Projections:
In a thriving D4Ag ecosystem, Latin America and the Caribbean could generate an extra income of US$115 billion over the next decade, driven predominantly by reduced crop and animal loss, increased quality of produce and improved labor efficiency. However, if the "derailing" scenario is realized, it might drastically reduce this figure to just 10% of the potential.



Source: USDA ERS International Agricultural Productivity indices, Beanstalk analysis

Figure 85. Economic Projections Latin America and the Caribbean

Social Projections:
Within Latin America and the Caribbean region, current D4Ag adoption rates stand at 17%, on average, in 2023. We expect that countries like Brazil might achieve a 71% D4Ag adoption rate by the decade's end. Similarly, nascent nations might see up to 20% of their farmers adopting D4Ag solutions. Moreover, a thriving scenario could lead to 26% females employed in agriculture using D4Ag tools and bringing the gender gap down by 44%.

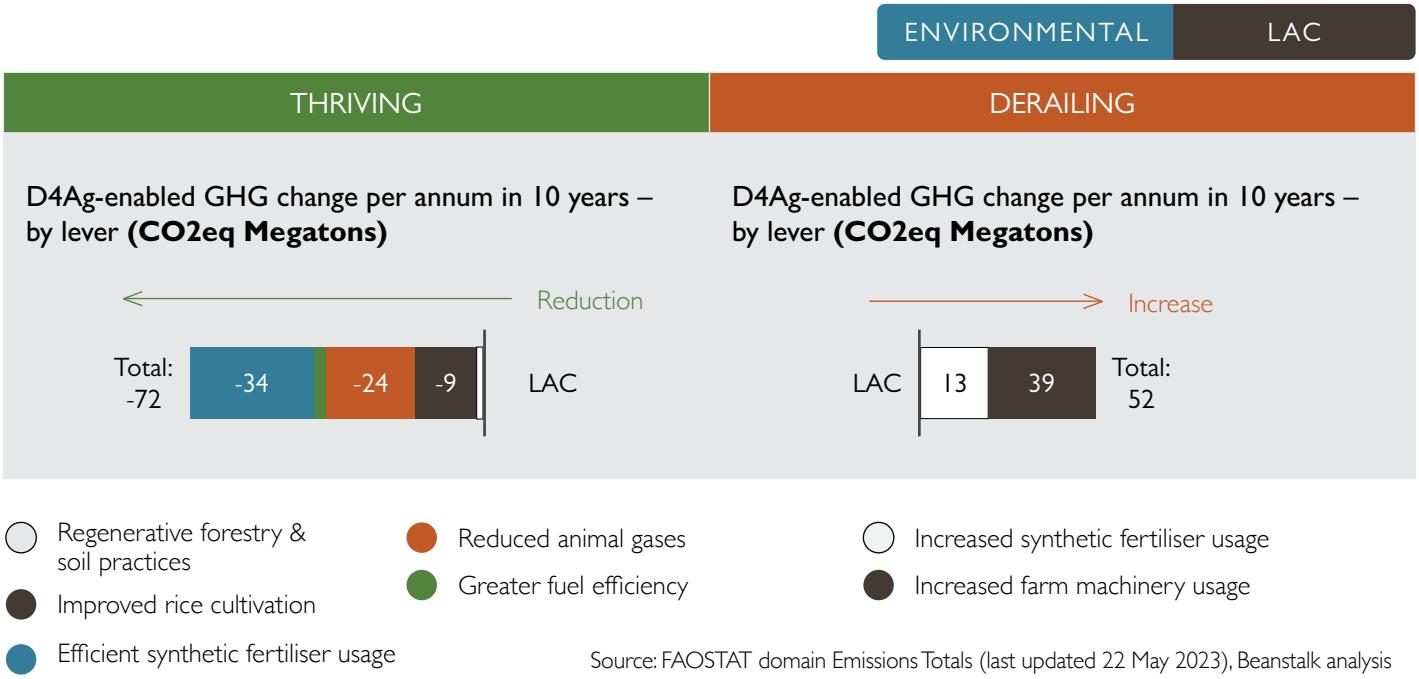


Note: Available data was extremely limited. Available country data was extrapolated to represent the entire progression status per region. Where data was not available, the 2016 Digital Adoption Index (DAI) was utilized to estimate current adoption levels. The thriving scenario was projected by using the internet adoption curves of each country with an adjustment factor. Relative to internet adoption, the following lag was assumed for D4Ag adoption: Leaders – 10-year lag, Emergent – 12-year lag, Nascent – 15-year lag.

Source: Various, World Bank World Development Indicators (Individuals using the Internet (% of population)), Beanstalk analysis

Figure 86. Social Projections Latin America and the Caribbean

Environmental Projections:
Latin America, under thriving conditions, might focus on regenerative forestry and soil practices, as well as reduced animal gases for environmental impact, resulting in emissions decrease of 72 megatons CO2eq, annually. The "derailing" scenario could actually bring the emissions up by 52 megatons CO2eq per year due to increased synthetic fertilizer and farm machinery usage.



Source: FAOSTAT domain Emissions Totals (last updated 22 May 2023), Beanstalk analysis

Figure 87. Environmental Projections Latin America and the Caribbean

APPENDIX 5. LIST OF INTERVIEWED STAKEHOLDERS

Name	Role	Organization	Country
Abhilash Thirupathy	Founder	AgriFi	India
Adaeze Usoh	Head of Corporate Finance & Investor Relations	BabbanGona	Nigeria
Adegbola Adesogan	Director of Strategic Partnerships	University of Florida	United States
Afrina Choudhury	Senior Gender Specialist	WorldFish	Bangladesh
Agam Khare	Founder & CEO	Absolute	India
Ainee Islam	Director Program Development	The Asia Foundation	Bangladesh
Akindele Phillips	Co- Founder & CEO	FarmCrowdy	Nigeria
Albert Boogard	Head Smallholder Solutions	Rabobank	Netherlands
Albert Luogon	Country Director	iLab Liberia	Liberia
Alekh Sanghera	Co-Founder/CEO	FarMart	India
Alex Jones	Manager	Ariaponics Ltd	Trinidad and Tobago
Alexandre Monteir Chequim	CEO & Co-Founder	DigiFarmz	Brazil
Alice Nkunzimana	President & CEO	Papyrus, SA	Haiti
André Fukugauti	Brazil Innovation Manager	Bayer Crop Science	Brazil
Andrew Hicks	Head of Program Strategy Support	Digital Green	United States
Anne Maftei	Portfolio Lead /Gender & Business Expert	Value for Women Ltd	Canada
Anthony Kofituo Morrison	Founder & Director	Chamber of Agribusiness	Ghana
Anton Eitzinger	Research Leader for Digital Climate Action	Alliance of Bioversity International and CIAT	Colombia
Anton Wibowo	CEO	Trendlines Singapore	Singapore
Anuj Kumbhat	Co-Founder &CEO	WRMS	India
Ariadne Caballero	Partner	SP Ventures	Brazil
Arindom Datta	Executive Director, Rural & Development Banking/Advisory	Rabobank	India
Ashish Khetan	President & CIO	Indigram Labs Foundation	India
Ashley Olson Onyango	Head of Financial Inclusion and AgriTech	GSMA	United Kingdom
Atika Benedikta	Impact Investment Lead	ANGIN	Indonesia
Ayon Hazra	Founder & CEO	Bolarug Web Services	Netherlands
Baskar Reddy	Executive Director	Syngenta Foundation India	India
Beatriz Esteves	Marketing Manager	Tarken	Brazil
Beau Damen	Natural Resources Officer- Climate Change and Climate Finance	FAO	Thailand
Bhavik Doshi	Research and Impact Manager	MEST Africa	Ghana
Boniface Akuku	Director of ICT	KARLO	Kenya

Name	Role	Organization	Country
Brian Cohen	Senior Director, Environment and Climate Change	ACDI/VOCA	United States
Bruno Matozo	Head B2F	Seedz	Brazil
Callum Mackenzie	Co-Founder & Managing Director	Yunus Thailand	Thailand
Calvince Okello	CEO	M-SHAMBA	Kenya
Cassandra Mtine	CEO	AgriPredict	Zambia
Chris Aurand	Open Innovation Leader	Thai Union Group PCL	Thailand
Christabell Makokha	Senior Director, Innovation	CARE	Kenya
Christian Ntieche	Co- Founder & CEO	itkola	Cameroon
Christina Tewes-Gradl	Managing Director	Endeva	Germany
Cilliers Geldenhuys	Co-Founder	Agrigistics	South Africa
Claude Munyangabo	CEO	BK Tech House Ltd	Rwanda
David C.Y. Chen	Chief Executive Officer	Agrig8	Singapore
David Davies	Founder CEO	AgUnity	Australia
Deise Nogueira	Post – Doctorate Researcher	Quanticum	Brazil
Dhruv Sawhney	COO	nurture.farm	India
Diana Francis	Regional Specialist, Policy & Trade	IICA	Trinidad and Tobago
Diego Siqueira	Executive Director	Quanticum	Brazil
Diego Stone Aires	CXO - New Business & External Affairs Director	Krilltech NanoAgtech	Brazil
Diego Valencia Lopez	Head of Development - Spain & LATAM	GoRamp	Peru
Donald Nkrumah	Individual contributor		USA
Dr. Chitundu Kasase	Director & CEO	National Technology Business Center	Zambia
Dr. Eileen Bogweh Nchanji	Gender & Social Inclusion Expert	Alliance of Bioversity International and the International Center for Tropical Agriculture	Kenya
Dr. Gilbert Arap Bor	Member	Global Farmer Network	Kenya
Dr. Harikrishna Kulaveerasingam	Chief R&D Officer	Sime Darby Plantation Research and Development	Malaysia
Dr. Namita Singh	Director-Strategy, Knowledge and MEL	Digital Green	India
Dr. Paul Coleman	Chairman	Ingabo Plant Health	Rwanda
Dr. Udaya Sekhar	Senior Research Scientist	NIBIO	United States
Dr. Wahida Maghraby	Agriculture Attachee	ICASEPS	Indonesia
Eddy Fay	New Business Director	OCP Groupe	Argentina
Eduardo Crosara	Consultant	Learning Village	Brazil

Name	Role	Organization	Country
Elorm Goh	Executive Director	Agrisolve	Ghana
Emmanuel Ansah-Amprofi	Co-Founder & CEO	Trotro Tractor	Nigeria
Emmanuelle Bourgois	Founder & Managing Director	Fairagora Asia	Thailand
Eric Acquah	Founder	AcquahMeyer Drones Tech UG	Germany
Federico Sancho	Planning, Monitoring, and Evaluation Manger	IICA	Costa Rica
Fika Rahima	Office of the CEO	Crowde	Indonesia
Dr. Florian Muehlbauer	Project Director & Principal Policy and Legal Advisor	GIZ	Myanmar
Florentine Oberman	Strategic Partnership Manager	DSM- Firmenich	Netherlands
Gaston Santi Kremer	Program Manager	WTT	Brazil
Geoffrey Karenzi	Digitalisation Expert	The Farm2Go (UNWFP)	Rwanda
George William Luyinda	CoFounder & CEO	EzyAgric	Uganda
Gottfried Odamtten Sowah	Program Lead, Agribusiness	Mastercard Foundation	Ghana
Guilherme Castro	CEO & Co-Founder	Cromai	Brazil
Guilherme Kudiess	Partner, COO e Head Agtech	VEN TIUR	Brazil
Guilherme Raucci	Sustainability Manager LATAM	Syngenta	Brazil
Guillermo Valenzuela	Vice President of Sales and Marketing	Wiseconn	United States
Gustavo Righeto	LATAM Innovation Manager	Ellen MacArthur Foundation	Brazil
Dr. Irene Egyir	Associate Professor of Agricultural Economics and Agribusiness	University of Ghana Legon	Ghana
Israel Agbeti	Director of Operations & MEST Consultancy	MEST Africa	Ghana
Jacob Nyirongo	CEO	Farmers Union of Malawi	Malawi
Jacob van Etten	Research Director, Digital Inclusion	Bioversity International	France
James Hansen	Director, Climate Science	Columbia Climate School	United States
Jenn Williamson	Vice President, Gender & Social Inclusion	ACDI/VOCA	United States
Jinesh Shah	Managing Partner	Omnivore	India
Johanan Dujon	Founder/ CEO	Algas Organics	United States
Jorre Vleminckx	Chief Innovation Officer	myAgro	Senegal
Jose Mesa	Consultant		Colombia
JT Solis	Co-Founder & CEO	MAYANI	Philippines
Judith Ngonyo	Senior Investment Associate	Goodwell Investments	Kenya

Name	Role	Organization	Country
Julio Martinez Anderson	Strategic Alliances Manager	Pomona Impact Foundation	Guatemala
Jules Somé	Country Director	AGRA	Burkina Faso
Keithlin Caroo	Founder & Executive Director	Helen's Daughters	Saint Lucia
Ken Lohento	Digital Agriculture Expert	FAO	Netherlands
Keron Bascombe	Agri Journalist	Tech4Agri	Trinidad and Tobago
Khan Jean-Delmas Ehui	CEO & Co- Founder	ICT4DEV	Ivory Coast
Kieran Gartlan	Managing Partner	The Yield Lab LATAM	Brazil
Kizito Odhiambo	Founder & CEO	agriBORA	Kenya
Kristian Schach Moller	CEO	Agricultural Commodity Exchange for Africa	Malawi
Lam Nguyen	Founder, CEO	Tepbak	Vietnam
Laura Johnson Blair	Consultant- Climate Finance	World Bank Group	United Kingdom
Léa Guignard	Programme Development Officer	Enablement LTD	The Netherlands
Luca Torre	Founder & Co-CEO	GAWA Capital	Spain
Luis Flores	Senior Technical Director, Agricultural Systems	ACDI/VOCA	USA
Luke Smith	AgriEduTainment & ICT Director	TFF & WhyFarm	Trinidad and Tobago
América Maria Castiblanco	Vice President of Entrepreneurship	iNNpulsa	Colombia
Maame Esi Owusu-Ansah	Partner	Mastercard Foundation	Ghana
Marci Baranski	Programme Management Officer	UNEP	Thailand
Margaret Mugo	Geospatial Information and Digitalization Expert in Water and Land Monitoring and Management	FAO	Malawi
Maria Mateo Iborra	Co-Founder & CEO	IBISA Network	Luxembourg
Matheus Calheiros	Operations & ESG	IZagro	Brazil
Mauricio Britez Burró	Country Manager	Agrosmart	Paraguay
Muhammad Irfan Kasana	Individual contributor		Pakistan
Michael Ewuola	CEO	Opolo Global	Nigeria
Michael Oluwagbemi	Executive Partner	LoftyInc Allied Partners Limited	Nigeria
Mihayo Wilmore	Director & Operations Lead	AGRI INSIGHT	Tanzania
Mirko Zuerker	Head of Programme	SEED	India
Montha Kaihirun	Project Manager	National Innovation Agency	Thailand
Moses Mallaghan	CEO	Agro Innova Ltd	Ghana

Name	Role	Organization	Country
Mythri Sambasivan-George	Chairperson	Angel Network Botswana	Botswana
Munish Soni	Head of Business Strategy	Bayer CropScience	India
Naledi Magowe	Co-Founder & Chief Growth Officer	Brastorne Enterpirses	Botswana
Nawsheen Hosenally	Co- Founder and Associate Director	MEDIAPROD	Burkina Faso
Ndidi Okonkwo Nwuneli	Co-Founder Chair	Sahel Consulting Agriculture	Nigeria
Nicoline de Haan	Director, Impact Platform	CGIAR	United States
Nirjhor Rahman	CEO	Bangladesh Angels	Bangladesh
Olacio Kumori	Coordinator	CETAF Training and Technological Support Center for Family Farming	Brazil
Patrick Senga	CEO	Ingabo Plant Health	Rwanda
Paul Zaake	Co- Founder & Managing Director	AgriShare	Uganda
Phong Tran	Founder	Tepbac	Vietnam
Prabhat Labh	Founder & Director	PRARABDH Food and Future	India
Pravesh Sharma	Director	Samunnati	India
Prince Oby Ilosyo	Lead Farmer Coordinator	BIOS CHRISTI IN CONGO (BICCO)	Democratic Republic of the Congo
Quyen Ho McGrath	Head of Project & Partnerships	Village Link	Myanmar
Rachel Renie	Managing Director	Market Movers Ltd	Trinidad and Tobago
Rajesh Ranjan	CEO	Nabventures	India
Rakesh Munankami	Project manager	Helvetas	Nepal
Ranadeep Das	Managing Director & CEO	InGreens	India
Ranjith Mukundan	CEO & Co- Founder	Stellapps Technologies	India
Ratha Hem	Digital Agriculture Value Chain Consultant	SAAMBAT	Cambodia
Ricardo Campo	Digital Innovation Coordinator	Raízen	Brazil
Ristoto Martadiwirya	Founder & CEO	PT Karsasoft Bara Technology	Indonesia
Rodrigo Iafelice	Entrepreneur, Board Member, Solo VC, Apprentice & Trainee	Endeavor Scale-up	Brazil
Rodrigo Saad Rodrigues	Sustainability Director	My Carbon	Brazil
Rolly Calvo Muñoz	Agriculture and Resilience Specialist	Earthworm Foundation	Peru
Romy Cahyadi	Co – Founder & CEO	Instellar	Indonesia
Rohn Yearwood	CEO	Oxanic Grow	Trinidad and Tobago
Rose Funja	Managing Director & Founder	Agrinfo Social Enterprise	Tanzania

Name	Role	Organization	Country
Mamam Rouffahi Koabo	CEO	CIPMEN	Niger
Ruel Amparo	CEO & Founder	Cropital	Philippines
Saeed Ullah Khan	Director	GLOW Consultants	Pakistan
Samuel Thevasagayam	Individual contributor		United Kingdom
Samuel Campos	Co- CEO	Vega Monitoramento	Brazil
Sandra Uwantege Hart	Advisor, Climate Finance Innovations	Oxfam Aoteaora	United States
Sangita Budhathoki	National Gender Specialist	FAO	Nepal
Sanjay Vuppuluri	National Head, Food and Agribusiness Strategic Advisory and Research (FASAR)	Yes Bank	India
Sanjiv Kanwar	Country Manager	Yara International	India
Santanu Mukherjee	Regional Program Manager	Accion	India
Santiago Henao Restrepo	Director of Operations, Medellin Entrepreneurship and Innovation Center	Georgia Institute of Technology	Colombia
Saran Song	CEO	AMRU Rice (Cambodia) Co., Ltd	Cambodia
Sergio De Zen	Associate Professor	The University of São Paulo	Brazil
Sergio Rocha	CEO	Agrotools	Brazil
Shai Albaranes	Vice President of Innovations & Ventures	Orbia (previously Mexichem)	Israel
Shanoo Saran	Co-Head, Smallholder Solutions at Rabo Partnerships	Rabobank	UAE
Shreejit Borthakur	Technology Lead and Senior Innovation Manager	IDH- The Sustainable Trade Initiative	India
Silvia Maria Fonseca Massruha	President	Embrapa	Brazil
Srijita Dasgupta	Climate Change Programme Consultant- SCALA Coordinator	FAO	Thailand
Srinivas Ramanujam	CEO	Villgro	India
Srivalli Krishnan	Senior Program Officer- Global Development	Billl & Melinda Gates Foundation	India
Stephen Awuah	Regional Director, SSA (Africa)	Farrelly & Mitchell	Ghana
Subi Thomas	Founder & Co-Director	IDrone Services Limited	Zambia
Sulabh Dhanuka	International Digital Solutions Head	True Digital Group	Thailand
Sunjay Vuppuluri	National Head, Food & Agribusiness Strategic Advisory & Research	YesBank	India
Supapim Wannopas	National Coordinator	SEED	Thailand
Sylvia Chebi	Co-Founder & Executive Director	ThalesLab	Uruguay

Name	Role	Organization	Country
Tauseef Ahmad Khan	Cofounder & CEO	Gramophone	India
Tecila Ferracino de Souza	Innovation Coordinator	Stoller do Brasil Ltda.	Brazil
Todd Moore	Company Director	Saffron Coffee	Laos
Vidyuth Prashanth Premakumar	Founder & CEO	Agrithmics	Sri Lanka
Vijay Nadiminti	CEO	AgHub	India
Vishal Ajmera	Senior Director, Agri Lead	Accion	India
Vitor Mondo	Head of Technology Transfer	EMBRAPA - Digital Agriculture	Brazil
Walter Baethgen	Senior Research Scientist	International Research Institute for Climate and Society (IRI)	United States
Wangui Mukanu	Head of Enterprise	eVuna	Kenya
Wei-Li Woo	Innovation lead	Grow Asia	Singapore
Wissal Ben Moussa	Co-Founder and Chief Agriculture Officer	From Sand to Green	Morocco
Ye Min Aung	Secretary- General	Myanmar Rice Federation	Myanmar
Yin Phyu	Co-Founder & Business Development Director	Greenovator Co.,	Myanmar
Yuan-Ting Meng	Individual contributor		Taiwan

APPENDIX 6. GLOSSARY

Active Users

Accounts used regularly enough for users to feel the full benefit of the solution

Advisory & Information Services

Digitally delivered information on topics such as agronomic best practices, pests and diseases, weather, and market prices, as well as more sophisticated digital services and farm management software tailored to the specific farmer, farm, or field that enable smallholder farmers to make decisions that maximize output from their land, improve the quality of agricultural production, and maximize farm revenues and profits via lower costs of production, improved ability to identify markets, and/or better price realization.

Agribusiness

Businesses collectively associated with the production, processing, and distribution of agricultural products, including business entities involved in the production and distribution of agricultural inputs and machinery to farmers and those involved in purchasing, aggregating, processing, and distributing farm produce.

Agtech

Agricultural technology or agrotechnology is the use of technology in agriculture, horticulture, and aquaculture with the aim of improving yield, efficiency, and profitability. Agricultural technology can be products, services or applications derived from agriculture that improve various input/output processes.

Bundling

Marketing and distribution strategy that joins multiple products or services together to sell them as a single combined unit in order to deliver more value to consumers and/or more economic benefits to the business offering the products; in the context of this report, refers specifically to solutions that cover two or more D4Ag use cases.

Climate Market Access

Services that use digital tools to integrate farmers into emerging markets based on climate-friendly and sustainable agricultural practices. They align farmers with opportunities in the growing climate economy, such as carbon offset markets, sustainable certification programs, or markets seeking produce cultivated with reduced environmental footprints.

Climate-Smart Agriculture (CSA)

Is an integrated approach to managing landscapes to help adapt agricultural methods, livestock and crops to the effects of climate change and, where possible, counteract it by reducing greenhouse gas emissions from agriculture, at the same time taking into account the growing world population to ensure food security.

Climate-Smart D4Ag

Integration of digital technologies into agricultural practices to enhance adaptation to climate change, reduce greenhouse gas emissions, and improve sustainability by leveraging innovations in data, analytics, and connectivity.

Credit

Platforms that provide digital lending services, offering farmers loans based on credit assessments. By providing loans based on digital credit assessments, these platforms can reach farmers who would otherwise be excluded from traditional credit markets.

Customer Relationship Management

Systems that help agribusinesses manage their relationships with customers, including tracking interactions, managing customer inquiries, and forecasting demand.

d-MRV

An approach to monitoring and evaluating climate change mitigation efforts that uses digital technologies and data analytics.

D4Ag

A broad terminology encompassing a vast array of digitally enabled solutions aimed at fostering the growth and fortifying the operations of entities throughout the agricultural value chain, from smallholder farmers operating at the grassroots level, to multinational corporate agribusinesses exerting influence on a global scale.

D4Ag Ecosystem

An interconnected community of stakeholders, technologies, and practices that collectively contribute to the advancement and implementation of digital solutions in the agricultural sector.

D4Ag Solution

A specific application of D4Ag (provided by a startup, NGO, government, or other entity) that leverages digital tools, data, and platforms to provide targeted services, products, or interventions within the agriculture sector.

D4Ag Use Case

The practical application of digital tools in agricultural contexts solving a particular problem or achieving a defined goal. Each use case may encompass a broad spectrum of solutions within it.

Digital Insurance

Products that allow smallholder farmers access insurance products tailored for agriculture, like crop insurance, livestock insurance, etc. These services can help farmers manage the risks associated with agriculture, protecting them from financial losses due to factors like adverse weather, pests, or disease.

Digital Marketplaces

Platforms that connect farmers directly with buyers and input providers, facilitating transparent and efficient transactions. They eliminate the need for middlemen, allowing farmers to retain a higher proportion of the sale price for their products. They also make it easier for farmers to access quality inputs at competitive prices.

Digitally Enabled Value Chain Integrators

Platforms that leverage digital technologies to better integrate value chain activities from farmers to consumers. Their primary

goal is to bring value and create a beneficial impact for both small-scale farmers and large agribusinesses by streamlining and formalizing what is typically a disorganized and informal series of value chains.

Engaged Users

Those users who know how to use the solution and have done so, at least one monthly in the past year.

Farm Management Software (FMS)

Services that aid farmers and other value chain actors in managing their day-to-day farming operations more efficiently. This covers areas like crop planning, labor management, inventory control, financial tracking, and more.

Farmer Information Services

A platform that provide farmers with relevant and timely agricultural information, including weather forecasts, market prices, and agricultural best practices.

Farmer

Primary producers, including not only traditional farmers who cultivate crops but also ranchers who manage livestock, and fisherfolk who harvest fish.

Logistics Management

Platforms or software that assist with coordinating and managing the transportation of agricultural goods. They can optimize routes, track shipments, and help manage inventory, reducing inefficiencies and potential losses.

Low- and Middle-Income Country

Nations that have gross national income (GNI) per capita within certain defined thresholds. As of 2022, the World Bank classifies low-income countries as those with GNI per capita <US$1,136; lower middle-income countries GNI per capita between US$1,136 and US$4,465; upper middle-income countries GNI per capita between US$4,096 and US$12,695.

Machinery and Equipment Access

Platforms that provide farmers with access to farm machinery and equipment on a pay-per-use or lease basis, reducing the need for significant upfront investment. These platforms can also promote the sharing of resources among farmers, which can help to reduce waste and improve sustainability.

Macro Intelligence

Services that involve large-scale data analysis to provide insights on market trends, risk factors, and opportunities within the agricultural sector. These insights are primarily geared toward stakeholders like policy makers, agribusiness companies, and investment firms. While they are not typically farmer-facing, these services can indirectly impact farmers by influencing agricultural policies, business decisions, and investment strategies in the sector.

Participatory Advisory

Services that facilitate farmer-to-farmer information sharing and learning, usually through digital communities.

Payments

Platforms that enable easy and secure monetary transactions between agricultural stakeholders.

They can reduce transaction costs, facilitate timely payments, and provide a record of transactions that can be useful for things like credit assessments.

Peer-to-Peer Lending / Crowdfunding

Platforms in the context of financial access for agriculture that connect farmers directly with lenders or investors, enabling the exchange of funds without the need for a traditional financial institution as an intermediary.

Post-Harvest Quality Control

Platforms that help monitor and manage the quality of agricultural produce post-harvest to reduce losses and ensure food safety. They can provide real-time monitoring of storage conditions, provide alerts for potential quality issues, and even assist in troubleshooting solutions.

Precision Agriculture Advisory

Services that leverage advanced technologies, like AI, IoT, and remote sensing to provide farmers with precise information about their farms, helping them to optimize crop production.

Registered Users

The number of registered accounts in the database

Savings

Digital financial services that allow farmers to securely save money, often offering interest. They can help farmers manage their cash flow, save for future investments, and provide a cushion against unforeseen expenses. These services can be particularly beneficial for smallholder farmers who might not have access to traditional banking services.

Smallholder Farmer

Individuals who produce crops or livestock on two or fewer hectares of land.

Super-Platform

Type of D4Ag solution which bundles together multiple different services for farmers or other smallholder value chain intermediaries and, typically, integrates digital market linkage services, advisory services, and financial services, among others.

Youth

Persons between the ages of 15 and 24 years.

Value Chain Traceability

Systems that track and document the journey of agricultural products across the value chains ensuring transparency and accountability. By providing a clear picture of each step in the supply chain, these tools can help prevent fraud, improve quality control, and provide consumers with valuable information about the products they buy.

APPENDIX 7. ABBREVIATIONS AND ACRONYMS

AI	artificial intelligence
API	application programming interface
ASEAN	Association of Southeast Asian Nations
ATA	Agricultural Transformation Agency (Ethiopia)
BMGF	Bill and Melinda Gates Foundation
CAGR	compound annual growth rate
CSA	climate-smart agriculture
CGIAR	Consortium of International Agricultural Research Centres
COMESA	Common Market for Eastern and Southern Africa
CRM	customer relationship management
CTA	Technical Centre for Agricultural and Rural Cooperation
D4Ag	digitalization for agriculture
DCAS	digitally-enabled climate advisory services
DFI	development finance institution
ERP	enterprise resource planning
FAO	Food and Agriculture Organization of the United Nations
FCDO	Foreign, Commonwealth & Development Office
FMCG	fast-moving consumer goods
GARDIAN	Global Agricultural Research Data Innovation Acceleration Network
GDP	gross domestic product
GESI	gender equality and social inclusion
GHG	greenhouse gas
GIIN	Global Impact Investing Network
GSMA	Global System for Mobile Communications Association
IFC	International Finance Corporation
IFPRI	International Food Policy Research Institute
IICA	Inter-American Institute for Cooperation on Agriculture
ILRI	International Livestock Research Institute

IoT	internet of things
IRRI	International Rice Research Institute
ISF	Initiative for Smallholder Finance
ITU	International Telecommunications Unit
IVR	interactive voice response
LAC	Latin America and the Caribbean
LMIC	low- and middle-income country
ML	machine learning
MRV	measurement, reporting, and verification
NGO	non-governmental organization
NRDC	Natural Resources Defense Council
OECD	Organization for Economic Cooperation and Development
PE	private equity
R&D	research and development
SA	South Asia
SAARC	South Asian Association for Regional Cooperation
SAAS	software-as-a-service
SEA	Southeast Asia
SMS	short message service
SSA	Sub-Saharan Africa
TAM	total addressable market
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USSD	unstructured supplementary service data
VC	venture capital

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DATA ANALYSIS RESOURCES

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164. Indigo Ag pays farmers $15 per verified tonne of CO2. See https://www.spglobal.com/esg/insights/topics/carbon-farming-opportunities-for-agriculture-and-farmers-to-gain-from-decarbonization

165. Relative yield (Ya / Yw) for cereals on rainfed land, used as proxy for yield gap in each region. https://www.yieldgap.org/gygaviewer/index.html?extended=1

166. Digital Adoption Index last updated in 2016. https://www.worldbank.org/en/publication/wdr2016/Digital-Adoption-Index

167. Individuals using the Internet (% of population) last updated 25/07/2023 https://data.worldbank.org/indicator/IT.NET.USER.ZS

168. See Figure 2.2 Agricultural employment figures of FAO report

169. https://www.fao.org/3/cc5343en/cc5343en.pdf

170. See Enteric Fermentation, On-farm energy use, Rice Cultivation and Synthetic Fertilizers in data set

171. https://www.fao.org/faostat/en/#data/GT

172. See Agricultural machinery, tractors per 100 sq. km of arable land

173. https://data.worldbank.org/indicator/AG.LND.TRAC.ZS

174. See Fertilizer consumption (kilograms per hectare of arable land)

175. https://data.worldbank.org/indicator/AG.CON.FERT.ZS