CIFAR ALLIANCE

Climate Resilient Agriculture (CRAg) Whitepaper

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Summary

Shocks from conflict in Ukraine and the COVID-19 pandemic are today impacting the food security of vulnerable populations globally. Climate change represents an even greater threat in the longer-term and adaptation is essential to creating more resilient global agri-food systems. This white paper examines the prospects for adaptation leveraging digital technology focusing on how solutions can be financed. Finance here is not regarded as simply another input in agriculture alongside seeds or fertilizer – rather it represents decision-making about what futures will be pursued and how uncertainties will be handled. Nor can finance be considered in isolation from the real-world problems it needs to solve. Members of the Climate Resilient Agriculture (CRAg) Working Group have already been involved in many initiatives relevant to shaping financial markets in developing economies with a strong focus on smallholder agriculture. The paper sets out a basic framing to help unpack the challenges faced, draw insights from on-going innovation and identify the key frontier issues which CRAg members and others need to tackle in order to accelerate change.

Nearly three-quarters of the world's estimated 570 million farmers cultivate less than one hectare. An enormous emphasis has been placed by government and development agencies on supporting smallholder-based food production systems but often with disappointing results. This has led to some pessimism regarding the future of small-scale agriculture. While some small farms will choose to grow rapidly others will adapt to operate successfully at a relatively modest scale finding new niches where advantage persists for smaller-scale operation. In short, adaptation does not mean the inexorable extinction of small-scale production. The digital revolution has directly and indirectly created a range of agri-food system innovations which open up new possibilities for tackling the challenges of transformation. The full potential of these technical innovations could transform smallholder agriculture – introducing transparency in information flows, creating cost efficiencies, strengthening the connection between value chain actors and ultimately improving farmer incomes.

Digital solutions in various forms have emerged as potential game-changers in both market functioning and the delivery of productivity enhancing solutions. What constrains the potential of these innovations? Taking a systems perspective on the agri-food sector, three broad inter-related aspects need to be considered:

a. **Integration and coordination in value chains.** This is a central problem in developing economies, characterised by numerous smallholder farmers and businesses with poor communication, weak physical infrastructure, and ineffective formal institutions.

b. **Diffusion of innovation across value chain participants.** Even where innovations are ostensibly well engineered for the context, frameworks of understanding, values, and risk perceptions play a significant role in shaping the diffusion of innovation and hence the adoption of productivity and resilience enhancing technologies.

c. **Financing innovation end-to-end.** The transformation of agri-food systems generally requires upfront investment and dealing with the problem of the inherent risks posed by change. Smallholders and small-scale firms in agrifood systems are frequently especially constrained in their ability to raise the finance to enable a shift from business-as-usual.

To be effective a strong collective effort is needed by development actors to determine practically how the promise of digital technology can be harnessed in a way which addresses the practical problem of change – many of which fall within the locus of these three areas. Finding viable routes to financing prospective transformation pathways to resilience will be decisive. The CRAg working group has the opportunity to play a catalytic role in enabling collaboration across a diverse set of actors seeking to exploit the potential of digital to unlock resilient agricultural transformation. Its strength at the outset will lie in combining the diversity of specific problems, solutions and activities in which the group is involved with pursuing a shared learning agenda drawing on this diversity.

1 Resilience and agri-food systems

Enormous progress has been made in agricultural productivity in many parts of the world. The US is a net food exporter with only 1.3% of its workforce directly engaged in agriculture.[1] Meanwhile, agricultural productivity in the world's developing regions remains low. Smallholder farmers in Africa and Asia are often among the poorest individuals in their respective countries facing poverty, hunger, and malnutrition.

Nearly three-quarters (72%) of the world's estimated 570 million farmers cultivate less than one hectare[2] and comprise a large proportion of the world's poor, who live on less than $2.15 a day.[3]

Female farmers have lower rates of agricultural productivity than male farmers. The productivity gap gives rise to a huge opportunity for economic, social and climate[4] impact: growth generated by the agriculture sector in sub-Saharan Africa is estimated to be eleven times more effective in reducing poverty than growth in all other sectors.[5]

Climate change is now impacting already fragile agri-food systems further undermining the resilience of smallholder farmers and those dependent on agriculture. Changes in temperature and precipitation patterns, increased frequency and intensity of extreme weather events, changes in pest and disease cycles, decreased water availability and loss of soil fertility mean that many current systems of agricultural production will no longer sustain even meagre livelihoods. The case for agricultural transformation in many developing economies is stronger and more urgent than ever.
The digital revolution creates new possibilities for change and an unparalleled opportunity to achieve this transformation.

[1] Source: US Department of Agriculture, Economic Research Service using data from US Department of Commerce, Bureau of Economic Analysis (SAEMP25N) data as at 30th Sept 2022, available here.

[2] Lowder, S.K., Skoet, J. & Raney, T. (2016) "The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide", World Development Vol 877, Nov 2016 pp.16-29, available here.

[3] See Fu, H. & Van Nieuwkoop, M. (2023) Mind the gap: enabling data-smart agriculture for all (worldbank.org)

[4] Improving agricultural productivity has a direct economic impact, enabling increased value addition, raising the incomes of farmers, and reducing the prices of food. This has direct social benefits by improving the livelihoods of lower-income households who are disproportionately engaged in agriculture and in whose budget food generally plays a greater role. Meanwhile, climate impact can be mitigated through better use of existing farmed land, which reduces pressure on opening open new tracts and deforestation. Greater productivity may also be associated with reduced waste and improved soil health and biomass.

[5] https://agra.org/news/africas-smallholder-farmers-are-the-linchpin-to-economic-success/

2 Climate resilient agri-food systems transformation

Some care is needed in attempting to define just what is meant by successful transformation. The UN's sustainable development goals (SDGs) offer some necessary features of what a resilient global food system would look like. These provide useful pointers, even if incomplete:

i. **Tackles hunger –** produces the quantity of food needed to support the world's population and distribute it effectively (SDG 2)

ii. **Supports health and nutrition –** the quality of food provides the diversity of nutrients necessary for humans to flourish and avoids diets that harm health (SDG 3)

iii. **Reliability –** meets global demands for food over time (SDG 2)

iv. **Sustainable –** production which aligns with a path to Net Zero and does not deplete the ecological resources on which both agriculture and every other aspect of life on earth depends (SDGs 12, 13, 15)

Transformation of agri-food systems has been a long-standing aspiration for countries in the global South emerging from the colonial period as a driver of food security and wider economic development. The Green Revolution which started in the 1960s was focused on farm level productivity, exploiting new varietals, fertilisers, herbicides and pesticides alongside mechanised tillage and irrigation. Results in a limited number of targeted crops in Latin America and Asia were dramatic. Africa, meanwhile, generally failed to make much headway where the background context was almost invariably less favourable from a socio-political and economic perspective.

The world's poorest and most food vulnerable regions are characterised by highly disaggregated, very small-scale production in marked contrast to the world's most productive regions which are closely integrated and based on large-scale production. The success of the latter leads to an increasingly industrialised agricultural modernisation pathway. Emphasising the prospective returns from increasing capital intensity and economies of scale, it remains a major theme in agricultural development. Major agro-industrial corporations are now turning their attention to the resilience challenge. There are, however, major difficulties with this approach. Measured by the yardstick of the four SDG derived pointers above, while agricultural industrialisation historically delivered on its immediate goal of tackling hunger, it has become increasingly evident that it scores poorly against the other three. These challenges are not new. Many solutions have already emerged to known problems ranging from preserving soil fertility through low-tillage to improving diets and drastically reducing environmental impact through reduced consumption of meat and refined sugars. Other as yet unproven technologies such as perennial cereals and precision fermentation hold considerable promise. The slow progress against potential suggests systemic constraints. Growing scale and concentration in the agri-food industry at a global level is associated with market power and the exertion of disproportionate political influence over policy and regulation especially where it is set to impact adversely on established business models and interests.[6]

> **Farming is the world's greatest cause of environmental destruction—and the one we are least prepared to talk about.** We have ploughed, fenced, and grazed great tracts of the planet, felling forests, killing wildlife, and poisoning rivers and oceans to feed ourselves. **Yet millions still go hungry and the price of food is rising faster than ever. Now the food system itself is beginning to falter**
>
> – from the introduction to Monbiot, G., (2022).

[6] An obvious highly relevant illustration of this is in relation to the problem of environmental externalities such as greenhouse gas emissions and pollution but also growing concerns over nutrition. Regulatory action has frequently been resisted as a result of successful industry lobbying (Clapp, J.,2023)

Moreover, development pathways involving sharp changes in complex socio-economic systems have often produced unanticipated adverse impacts and failed to deliver the outcomes sought. With large populations directly dependent on small-scale agriculture for their livelihoods, displacement by more concentrated forms of production creates intractable distributional and thus political economy challenges.

As a result, an enormous emphasis has been placed by government and development agencies on supporting smallholder-based food production systems but often with disappointing results.[7]

With reasons to be sceptical over the viability of transformation based on either a dash towards intensive industrialised farming or only very gradual incremental improvements in basic smallholder production, what would a viable pathway look like? Elements of both seem essential. Smallholder agricultural production based on traditional farming methods cannot sustainably feed eight billion people, leave aside the nearly ten billion projected for 2050[8] under significantly less favourable ecological conditions in many places. But the environmental impact of current intensive industrial farming technology renders it unviable. Even where the basic science and core technologies necessary to move towards resilience have already been developed,[9] rapid practical application remains a central problem to solve. Each step of the pathway to change has to be viable economically, socially and politically.

A prospective third way can be conceived which seeks to steer between the two polar extremes. This could be characterised by eclecticism which seeks to balance the need for some degree of farm expansion, intensification and consolidation (for the familiar reasons of technical scale economies and benefits from division of labour/specialisation) with reducing the concentration of market power and increased flexibility. Thus, rather than implicitly assuming that all smallholder farms need to be reached and modernised, this pathway admits the notion of differentiation.

Some small farms will choose to grow rapidly and others will adapt to operate successfully at a smaller scale with some finding new niches where there can be advantages to smaller-scale operation.[10] Adaptation does not mean the inexorable extinction of small-scale production.

Organisationally the vision is one of increased rather than reduced diversity with a mixture of micro, small, medium and large players. It probably means much less at either extreme – fewer micro-farms/firms which may be below an efficient scale of operation (often a result

[7] See Section 4.1 "Barriers to the transformation of agri-food systems" in the background literature review paper for a discussion of the complex array of challenges involved, and Studwell, J., (2014) "How Asia Works" for a detailed discussion.

[8] United Nations, Dept of Economic and Social Affairs (2022) World Population Prospects 2022: Summary of Results, available here.

[9] Irrigation represents a centuries old solution to the vagaries of weather. More recent mature examples include drought resistant varieties, crop rotation, crop cover and reduced tillage. Precision agriculture represents a more frontier technology but which can nevertheless still be applied to smaller-scale production (see for example, Loures, L. et al (2020) "Assessing the Effectiveness of Precision Agriculture Management Systems in Mediterranean Small Farms"

[10] The notion of development pathways in smallholder agriculture is articulated in ISF Advisors & RAF Learning Lab (2019) State of the Sector Report: Pathways to Prosperity.

of land fragmentation) and very large-scale conglomerates which may exert excessive market power. This heterogeneity produces more adaptive market systems supporting increased innovation and greater resilience to factors that cannot be predicted with precision (the known unknowns) or foreseen at all (the unknown unknowns). Such systems are more likely to produce solutions to successful transformation measured against the multi-dimensional yardstick of the UN sustainable development goals outlined above.

Global experience suggests that there are multiple possible futures for agricultural development. Rapid progress has almost invariably reflected the articulation and successful execution of policies which enable viable development pathways. Furthermore, markets alone cannot tackle the urgent need to shift towards ecologically sustainable production.[11] What future emerges will depend on the wider system of supporting markets and institutions. Policy driven intervention can shape markets enabling choices to be made which optimise the outcomes for sustainable human development.

3 Innovation and new opportunities for transformation

The digital revolution has directly and indirectly created an even greater range of agri-food system innovations which open up new possibilities for tackling the challenges of transformation.

On the basis that the economic organisation of agri-food systems is central to what changes can occur practically and what will prove resilient, it is useful to consider how innovations impact on these systems. On one hand there are technologies which primarily impact on production itself. New seed varietals represent one obvious such agricultural technology which can directly impact on plant productivity. On the other those whose impact relates to how economic activity is organised whether within firms and farms or between them in markets. Digital platforms which allow farmers to readily sell their produce to distant markets illustrates this type of technology driven innovation. In simple terms, the former shapes what is productively possible within a given area driving yield and efficiency, setting to one side the problem of organising those production processes. Meanwhile, the latter focuses on what is organisationally possible and – crucially – determines the change path through which new productive technologies can be adopted.

Among the most significant production related innovations are precision agriculture, which uses sensors and drones to collect data on crops and soil conditions to optimize resource use, climate-smart agriculture, which blends traditional practices with new technologies to help farmers adapt to climate change, climate-resilient crop varieties, early warning systems and more accurate weather forecasts. Meanwhile, at an organisational level, key developments include farm resource planning systems, digital input and marketing platforms, pay as you go asset platforms, enhanced logistics, digital payments and other novel digitally delivered credit and risk solutions. These have direct impacts on productivity and resilience at the individual firm and farm level but also at a value-chain or system level. In relation to the latter, technology enabled co-ordination across value chains can reduce

[11] Emission of greenhouse gases represents just one of a number of negative externalities which undermine critical ecological systems on which human survival depends.

costs end-to-end and reduce waste. However, it is important to highlight the potential fragility of systems which are optimised solely for efficiency but have little or no tolerance for unforeseen adverse events or developments.[12]

The full potential of these technical innovations can transform smallholder agriculture by improving farmer income, introducing transparency in information flows, creating cost efficiencies, and strengthening the connection between value chain actors.

Although the impact remains uncertain, they hold great promise. Crucially, the innovations addressing the efficiencies and effectiveness of markets and firms/farms combined with new production technologies expand the prospective range of transformation pathways towards more resilient agri-food systems. However, many of these technologies have already been in the market for some time but with limited impact, highlighting the imperative of focusing on how they can be effectively deployed.

[12] See Monbiot, G., (2022) ch.2

4 Unpacking transformation pathways

> Successful East Asian states have shown that the way to [maximise output from agriculture] is to restructure agriculture as a highly labour-intensive household farming - a slightly larger scale form of gardening. This makes use of all available labour in a poor economy and pushes up yields and output to the highest possible levels …
>
> (Studwell, J., 2014)

A wide range of factors have been advanced to explain the limited success in transforming agriculture across many regions and value chains in the global South. These include: lack of investment, limited agricultural research and development, fragmented markets, lack of financial services for smallholder farmers, weak institutional and policy environments, political and economic instability, lack of government support, local heterogeneity, and - more recently - climate change. Many interventions have been designed to address these constraints but with generally patchy levels of success. What remains somewhat unsatisfactory in the various explanations of failure is unpacking why in some places and times it has been possible to make progress (see boxes highlighting successful agtech companies) – sometimes very rapidly – despite apparently similar conditions at the outset to contexts which have made limited headway. Or put another way, it seems easier to explain failure than predict success.

Effective exploitation of the new opportunities created by digital and other innovations in which the economic organization of the agri-food system – and specifically the role of smallholder production - is a central concern requires greater focus on the prospectively viable transformation pathways. It demands greater focus on three elements: (i) how market systems of farms and firms can be successfully improved, integrated and coordinated (the 'meso-level' perspective), (ii) the process by which innovations are adopted by market participants over time, and (iii) how this transformation process can be financed. These three elements are clearly strongly inter-related. This perspective doesn't seek to suggest that the many proximate constraints that have been identified are not material – rather it is simply looking to place them within the context of change dynamics with a view to finding pathways which are possible.

None of these three aspects of system change dynamics is new to the agricultural development field. Growing concerns over food system resilience and environmental sustainability have produced an increased emphasis on a more holistic systems approach.[13] The major challenge remains largely around praxis: how to manage complex multi-dimensional interventions over time which stimulate rather than displace market solutions. While successful agricultural transformation programmes in earlier periods shows that digital technology is not necessary to solving this problem, it nevertheless provides promising new tools which could make the task easier – especially pertinent where starting conditions may be less advantageous (notably in relation to state capacity, political economy and financial system development).

[13] See for example OECD

A particular emphasis is placed on the financing issue.

Finance cannot be regarded as simply another input alongside seeds or fertilizer – rather it represents decision-making about what futures will be pursued and how uncertainties will be handled.

Appropriately structured it can provide the 'glue' to coordinate multiple interdependent developments. It also of course encompasses the payments infrastructure function – often a crucial enabler of market functioning.

4.1 Integration and coordination

Integration and coordination among participants in agricultural value chains is a central problem in developing economies, characterised by numerous smallholder farmers and businesses with poor communication, weak physical infrastructure, and ineffective formal institutions.

Lack of access to reliable and affordable communication technologies and information, weak physical infrastructure, and ineffective formal institutions can lead to inefficiencies and barriers to market access, impacting on the viability of smallholder-based agriculture. These barriers to effective market functioning, so critical to disaggregated productions, provide a strong impetus to larger-scale farms and processors and vertical integration but lead to the problems already highlighted. The inherent greater challenges of integration and co-ordination have successfully been tackled in many contexts, historically through various forms of government intervention or co-operative development. In part reflecting a mixed track record of success, there has been greater emphasis on private sector led solutions in recent years. Digital platforms offer significant promise here potentially dramatically improving market functioning through enhanced information flows and supporting lower cost mechanisms to enable trading between distant market participants. This potential however depends on both the adequacy of digital infrastructure and effective human-digital interfaces – often significant constraints in remote communities.

DeHaat is an online marketplace for farmers in India that provides a wide range of agricultural services along the length of the value chain, including access to seeds, fertilizers, equipment, crop advisory, and market linkages. It provides AI-enabled crop advisory to farmers for more than 30 crops in regional languages. DeHaat is building AI-enabled technologies to revolutionize supply chain and production efficiency in the farming sector. Currently, DeHaat operates in 12 Indian agrarian states with an extensive network of 11,000+ DeHaat Centers and over 500 Farmer Producer Organizations, serving 1.8 million+ farmers. It has raised over $600 million in funding from investors such as SoftBank, Sofina Ventures, and Temasek.

4.2 Diffusion of innovations

The material incentives for the adoption of innovations necessarily depend on the specific technologies and the stage of the value chain in which it is being implemented. For farmers, digital

technologies such as precision agriculture can increase productivity and efficiency, and platforms connecting farmers with buyers can improve access to markets and pricing. For processors and manufacturers, digital technologies can provide benefits such as improved supply chain efficiency and better inventory management. For retailers and consumers, digital technologies can provide access to product information and improved convenience through online ordering and home delivery. However, the extent to which these incentives give rise to adoption can rarely be understood in terms of a raw 'business case'.

Farmerline is a social enterprise that aims to improve the lives of smallholder farmers in Africa by providing them with access to information and technology. The company has developed a mobile platform that provides farmers with information on crop cultivation, pest and disease control, and weather forecasting. The platform also allows farmers to connect with other farmers and experts. Farmerline has reached over 1 million farmers in Ghana, Kenya, and Uganda. The company has been recognized for its innovative use of technology to improve the lives of smallholder farmers.

Stellapps uses artificial intelligence to help 2.8 million dairy farmers in India improve their productivity and eff iciency. The company's app provides farmers with real-time data on their cows' health, fertility, and milk production. This data allows farmers to make better decisions about their herd management, such as when to breed their cows and how to feed them. Farmers who use the app have reported increased milk production, improved herd health, and reduced costs. Stellapps has also helped to improve the lives of rural communities by providing farmers with a more reliable source of income.

Core economic conditions in terms of various forms of capital endowment (land, finance, skills etc) determine the base potential for adopting innovation.

However, even where innovations are engineered for this socio-cultural context, frameworks of understanding, values, and risk perceptions play a significant role in shaping the diffusion of innovation and hence the adoption of productivity enhancing technologies.[14]

Some cultures may be more resistant to change while others are open to new ideas and technologies. Individuals and groups with a more analytical and scientific approach to understanding new ideas may be more likely to adopt them quickly. On the other hand, individuals with a more collectivistic orientation or a lower tolerance for risk may be more hesitant to adopt new ideas. Women are often marginalised in the adoption and use of digital technology in agriculture due to factors such as lack of access to resources, decision-making power, and digital literacy and skills. However, when women are provided with the necessary resources and support, they can be effective adopters and users of digital technology in agriculture. Youth can play a crucial role in the diffusion of digital technology innovations in agri-food systems. They are often the early adopters of new technologies and can serve as intermediaries in connecting farmers and other stakeholders with information and resources. In Africa and Asia, despite the strong attractions of urbanisation, youth are still heavily involved in smallholder farming and may

[14] See Rogers, E.M. (2003)

be important drivers of change, adopting digital technologies such as precision agriculture and mobile-based extension services.[15] The use of social media for "social agriculture" is popular among young, educated farmers and can facilitate the diffusion of innovation. Meanwhile many smallholder farmers, especially with limited or no literacy and numeracy, remain reliant on oral communication. Digitally enabled agents or interactive voice response (IVR) provide channels that can reach these segments.

4.3 Financing transformation

The transformation of agri-food systems generally requires upfront investment and dealing with the problem of the inherent risks posed by change. Smallholders and small-scale firms are frequently heavily constrained in their ability to finance transformation. Many already struggle with meeting basic working capital needs, and the longer-term investment requirements for significant change often present an insurmountable barrier. Managing risk presents a core challenge here. Agriculture already faces greater production and market risks than many activities. These are often amplified by climate change, especially given the covariance of various adverse impacts. Change itself necessarily introduces new risks. Low-income households frequently adopt a portfolio approach in investing whatever scarce capital can be raised with the aim of mitigating exposure to a single activity in a frequently unstable and unpredictable operating environment. This incremental approach directly limits the prospects for both rapid change and increasing capital intensity.

Acre Africa is a company that links smallholder farmers to index-based insurance providers. Its services are designed to help farmers protect their crops from weather-related shocks, such as droughts and floods. The uptake of Acre Africa's products has been strong. The company has over one million active users in Kenya, Malawi, and Tanzania. Acre Africa is also expanding to other countries, such as Mozambique and Zambia. Farmers who use Acre Africa's services have reported increased crop yields, improved food security, and reduced financial risk. Acre Africa has also helped to improve the lives of rural communities by providing farmers with a more reliable source of income.

Apollo Agriculture, based in Kenya, is a technology-driven company that aims to help small-scale farmers maximize their profits by providing them with customized farming advice, financing, and access to high-quality farm inputs. By leveraging advanced data analytics, satellite imaging, and machine learning, Apollo Agriculture offers tailored recommendations to individual farmers to improve their agricultural practices, reduce risk, and increase productivity. Apollo started operations in 2017 in Kenya, where it has been expanding rapidly, empowering more than 170,000 farmers to date, nearly half of them female. Apollo's solution builds financial and climate resilience and improves food security by providing access to financing and all the tools farmers need to farm profitably, increasing their crop yield by approximately 2.0-2.5x times.

The financial sector is frequently conflated with the wider financial system of which it forms only one - albeit highly significant - element.

A systems perspective points to four major elements found in most economies, albeit that the emphasis varies significantly: (i) the formal financial sector, (ii) embedded finance, (iii) informal/community-based finance and (iv) state finance.

[15] See for example https://www.cgap.org/blog/youth-in-agriculture-new-generation-leverages-technology; and https://www.platformlivelihoods.com/social-agriculture-%20key-takeaways-report/

Much financing activity is heavily embedded within real sectors: for example, large firms often finance growth through retained earnings and large agri-processing companies. Various informal or semi-formal community-based financing still frequently play a far greater role in the day-to-day financial lives of low-income people than formal institutions despite enormous improvements in financial inclusion. Finally, governments necessarily play a major role in the financial system. Domestic and international development finance institutions and specialist agricultural programmes have long sought to address the shortcomings of the financial sector in relation to agriculture and especially agricultural transformation.

Moreover, various forms of climate finance prospectively push far beyond the frontiers of commercial provision reflecting the task at hand – correcting the greatest market failure in human history.[16] It is essential to recognise the interconnectedness of these four elements of the financial system. Embedded financing, for example, may depend heavily on large-scale agri-processing firms being able to access lines of credit from the formal banking sector. Digital technology is already playing a significant role in enhancing the individual functioning of each element of the financial system and how they interrelate more effectively.

[16] See Stern, N. (2006) The Economics of Climate Change, Cambridge: Cambridge University Press

5 Harnessing digital technology for climate-resilient agricultural transformation

Digital technology has proven potential to improve agri-food systems in Africa and Asia by increasing productivity and market functioning. Crucially these technologies open up new pathways for transformation which can enable the adoption of solutions to the challenges of climate change throughout the value chain. Much is already being accomplished through market-based approaches.

Digital solutions in various forms have emerged as a potential game-changer in relation to both market functioning and delivering productivity enhancing solutions.

The application of digital to market functioning in agri-food systems has received considerable attention. Digital platforms standout here given the high profile disruptive impact of platforms on many other sectors globally. Platform businesses can be defined as those 'whose core function is creating value by enabling interaction among platform users' and contrasted with more familiar pipeline business models which 'create value through a relatively linear process of producing, distributing and, ultimately selling goods and services to consumers'.[17] Social media platforms and digital payments platforms exemplify solutions that reach across multiple markets, providing a form of new infrastructure – enabling solutions to be developed for all sorts of problems. WhatsApp and Facebook have been combined with mobile money platforms (such as M-Pesa and bKash) and digital payment systems (such as UPI in India) to effectively build bottom-up online marketplaces. Digital platforms specifically targeting agricultural market functioning are starting to demonstrate scale and the potential to support transformation in India (for example De Haat, described in a box earlier) and to a more limited extent in Africa (exemplified by Safaricom's DigiFarm in Kenya). However digital is also being applied successfully to transform more familiar pipeline business forms, improving the functioning of value chains. Large-scale agri-food buyers are increasingly digitalizing their supply chains. This can significantly improve the transactional environment for smallholder farmers embedded within value chains.

The impact on the productivity aspect of transformation derives from a combination of improved market functioning – enabling farmers to simply gain better access to conventional products and services necessary to improving yields – and enhancements in the supporting services through digitalisation. The latter include include software solutions to support enhanced farm management, tailored weather/climate information, agricultural advisory and financial solutions. Farmerline, Stellapps, Acre Africa and Apollo Agriculture (see boxes above) illustrate a range of digital solutions currently in the market.

How the various digital models will play out remains unclear at this stage. Digital platforms looking to provide new 'horizontals' suggest major opportunities for improving access by smallholders to input and output markets. The inherent openness of platforms promises to enhance competition and innovation. However, the danger is that insufficient attention is given to the transformation process and the three elements highlighted in this paper. Simply improving efficiencies across value chains through digitalisation will not necessarily translate into sufficient resilience.

[17] ISF Advisers & RAF Learning Lab (2021) Agricultural 'Platforms' in Digital Era: Defining the landscape

The extent to which a 'pure' digital platform simply bringing multiple participants together can address the integration and coordination problem, enable the diffusion of innovation and unlock financing of change is questionable. Two obvious problems arise – the limitations of the digital channel itself in reaching smallholder farmers, and the extent to which coordination will happen across multiple participants on a digital platform in the absence of a lead player orchestrating activity. Digital solutions that focus on adding value across specific agri-food system verticals provide this orchestration and may be more tailored to the specific needs of smallholder farmers. On the other hand, these may offer less immediate prospects for scalability and can produce a market structure in which farmers remain largely or entirely dependent on a single provider of supporting services. It is possible that hybrid forms may emerge in which at least some degree of competition may be enabled say for inputs or off-take over a platform, while the operator plays a stronger role in leading transformation.

The few market-driven successes thus far have generally drawn heavily on the very early-stage research, experimentation and pre-commercial investments by various development partners and governments. While progress has been made in utilizing digital technology in agriculture, the agriculture sector lags behind highly digitized and medium-digitized industries and the future trajectory is far from certain. Furthermore – crucially – the application to building a path to Net Zero and long-term climate resilience remains at a very early stage. The understanding of what is meant by resilience in this context is prospectively complex but can be addressed by reference to the relevant UN SDGs highlighted earlier which represent a global consensus. However quantifying targets against these goals is more challenging and will require further work.

Development partners will continue to have a strong role in both priming and shaping the development of solutions. Given the market failures confronted, solutions will necessarily involve engagements beyond the core market participants even if that is where much of the action necessarily lies. The scale of the challenge is daunting and systemic impact is beyond the reach of any individual agency or programme.

To be effective a strong collective effort is needed to determine practically how the promise of digital technology can be harnessed. Finding viable routes to financing prospective transformation pathways to resilience will be decisive.

Financial markets have generally not 'solved' for the problem of smallholder agriculture transformation in the absence of market-shaping measures and initiatives. With the need to now confront the market failures of climate change, the application of smart climate and development finance is likely to be crucial.

The CRAg working group has the opportunity to play a catalytic role in enabling collaboration across a diverse set of actors seeking to exploit the potential of digital and finance to accelerate resilient agricultural transformation. Its strength at the outset will lie in combining the diversity of specific problems, solutions and activities in which the group is involved with pursuing a shared learning agenda drawing on this diversity. This may lead to greater coordination of specific market building initiatives, first, where immediate synergies are revealed through mutual learning exercises and second, as the insights start to shape collective strategic approaches and the need for specific new initiatives. The CRAg WG welcomes other participants sharing its vision and seeking to build scalable, systemic solutions driven by rapid innovation grounded in market application.

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The CIFAR Alliance Climate Resilient Agriculture (CRAg) Working Group, co-chaired by GSMA, and MSC, comprises: BII, CGAP, FSD-Africa, GSMA, MSC, UNFoundation, and WRI