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UNLEASHING THE POWER OF DIGITAL ON FARMS IN RUSSIA – AND SEEKING OPPORTUNITIES FOR SMALL FARMS

Agriculture Global Practice
The World Bank Group

Unleashing the Power of Digital on Farms in Russia – and Seeking Opportunities for Small Farms

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Acknowledgments

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Abbreviations

AI	artificial intelligence
API	application programming interface
CEC	cation exchange capacity
CGD	Center for Global Development
DEM	digital elevation model
DTM	digital terrain model
EC	European Commission
EGRRP	Unified State Register of Soil Resources of Russia
ESDB	European Soil Database
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FASIE	Foundation for the Assistance to Small Innovative Enterprise
FMIS	farm management information systems
GGCMs	global gridded crop models
GIS	geographic information system
GODAN	Global Open Data for Agriculture and Nutrition
GPS	Global Positioning System
HYV	high-yielding variety
IBM	International Business Machines Corporation
IIASA	International Institute for Applied Systems Analysis
IIDF	Internet Initiative Development Fund
INSPIRE	Infrastructure for Spatial Information in Europe
ICO	initial coin offering
ICT	information and communication technology
IoF2020	Internet of Food and Farm 2020
IoT	Internet of Things
IS PGBD	Information System Soil and Geographic Database
ISRIC	International Soil Reference and Information Centre
ISSGDB	Information System Soil and Geographic Database
IT	information technology
NDVI	normalized difference vegetation index
NRCS	Natural Resources Conservation Service
ODbL	Open Database License
OEMs	original equipment manufacturers
OFIS	Olam Farmer Information System
PPP	public-private partnership
SMEs	small and medium enterprises
SSURGO	Soil Survey Geographic Database
STATSGO	State Soil Geographic Database
UAV	unmanned aerial vehicle
USDA	United States Department of Agriculture
WFP	World Food Programme
WRB	World Reference Base for Soil Resources
WSS	Web Soil Survey
WTO	World Trade Organization
WUR	Wageningen University Research

Introduction

Farming is changing—for some farms. Rapidly emerging technologies that capture, manage, communicate, and use information in digital form are dramatically transforming the way that farming and agribusiness are done across the globe—especially for large commercial farms. Nowhere is this more true than in the Russian Federation (box 1), where many large agri-holding companies operate at the cutting edge of the application of digital technologies. These large industrial farms, with sizable land and livestock holdings, possess the financial resources and the management know-how to own and leverage the most advanced technology. Some have sophisticated information technology (IT) staff to develop and manage digital approaches to many aspects of farm operations.

On some large farms in Russia today, links to satellites control farm machinery and customize the application of inputs to specific areas in farmers' fields. Hyperlocal weather information drives field-level activity and marketing decisions. Information platforms allow farmers to plan and monitor the use of their farm equipment and to find buyers and sellers for the products they use and produce. Pests and diseases can be identified remotely (using digital imaging from drones and satellites) and responses can be mobilized rapidly. Soil monitors measure soil moisture to trigger irrigation and enable new customized approaches to water management. Mobile phones send actionable signals to farm equipment. Sophisticated management applications help to do farm planning. Production and harvest monitoring tools make it possible to control the quality of farm products. For these reasons, among others, the Internet is a critical tool in their farming toolbox.

However, many of Russia's farms—especially small and medium farms—lack the connectivity and skillsets needed to take advantage of such technologies. Many of these small farms also lack the equipment and the know-how to take advantage of the transformational digital opportunities from which they might profit. Yet the ever-expanding connectivity and availability of information and communication technology (ICT) and digital tools could make it possible for transformational developments to happen on small, traditional, remote, and disadvantaged farms too.

The upside of technology adoption is evidenced in the domestic trajectory of yields and production. Between 1992 and 2016, the adoption in the early 1990s of new technologies such as new machines, as well as new seed varieties, allowed farms to gradually leverage big data, remote sensing, the Internet of Things (IoT), and artificial intelligence (AI). In the last two or three years, the State Statistics Service recorded wheat yield increases from an average of 1.9 tonnes per hectare in 1992 to 2.7 tonnes per hectare in 2016, as well as a nationwide increase in grain production of 1.5 times.[1] As of 2017, 28 of the 85 regions in Russia were utilizing precision farming techniques (Collinson 2018; Ministry of Agriculture of the Russian Federation 2018).

On the flip side, Russia has also witnessed the opportunity and production loss that comes from the low level of technology use. The loss is observed most significantly in the 30 percent of total production

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[1] Data are from the ROSSTAT Database.

Box 1. A note on farm structure in Russia

The structure of agricultural production by type of farm has changed substantially since the early years of the post-Soviet period. During the 1990s production in large agri-enterprises declined sharply as a result of outdated technology and lack of investment. Production on predominantly noncommercial household plots was more stable during that period. As a result, in the period 1991–2002, the share of household plots in overall production increased from 40 percent to 65 percent. In the 2000s, however, growth in the agriculture sector was supported by production in both household plots and agri-enterprises. After 2010 there was a shift toward commercial production driven by investments, government programs, and increasing demand. Such growth of commercial production was predominantly led by agri-enterprises (former kolkhoz and sovkhoz enterprises and new corporate agribusinesses) and an emerging new class of family farms. The role of household plots in total agricultural production therefore started to decline. A share of households registered as family farmers, but others exited agricultural production because of an aging population, health issues, migration, and the refusal of younger generations to do manual work on their own household plots.

The agrarian structure in Russia today is based on three types of farms: (1) agri-enterprises—large industrial farms with extensive land and livestock holdings that collectively control roughly 80 percent of all agricultural land and produce roughly 45 percent of agricultural GDP; (2) emerging family farms—individual farms operated by family famers and limited hired labor that collectively control roughly 10 percent of all agricultural land and produce roughly 5 percent of agricultural GDP; and (3) household plots—small land plots adjacent to rural homes that collectively control roughly 10 percent of all agricultural land and produce roughly 50 percent of agricultural GDP. Although many agri-enterprises are nearly the same in area farmed, management, and technology as collective farms from Soviet times, since 2000 some have become much more modern in terms of their market orientation, in their approach to farm management, and in the technologies that they employ.

Source: Authors, using Rosstat data.

lost during harvest without proper machinery, and the production loss that results from an unsatisfactory storage environment (Collinson 2018; Ministry of Agriculture of the Russian Federation 2018). In 2017 the country's investment in ICT for agriculture industry remained the lowest in the world at 3.6 billion rubles, an equivalence of 0.5 percent of total investment in fixed assets according to Rosstat data.

The developments and tools mentioned above are transforming farming and agribusiness in Russia and across the world. They are raising productivity and driving increases in value added and incomes in farming—however, as suggested above, they also bring with them the possibility that smaller farms might be left behind. This does not have to be the case. But ensuring that small and poor and remote farms share in the benefits of digital advances may, at least in some dimensions, require proactive assistance from the public sector. The emergence of digital tools and technologies is also making it possible for public programs and policies to be more efficient, relevant, evidence-based, tailored and targeted, transparent and monitorable, and generally more effective than ever before in their support of agriculture. As a result, the public sector has the possibility of playing new roles and using new digitally enabled methodologies to support the agriculture sector—and it has new tools to work proactively with small farms to ensure that they are not left behind.

This technical note accompanied, and served as resource material, for a conference on digital agriculture that was held in Moscow on May 15, 2018. The note provides a survey of many ways in which ICT and digital tools are being used in Russia and globally to transform agriculture. It examines instances in which there are public and private collaboration entry points for expanding the benefits of digital technologies to small and medium farms in Russia. As evidence shows, small and medium farms in Russia are underserved by government programs and underperform if generally compared with large farms (Hakobyan and others 2017). However, these farms have the potential to expand production, be more competitive, and enter niche and premium markets where large agro-holdings may not be competitive. The emergence of digital technologies for farms and agribusiness can be harnessed, with the help of the public sector, to help small and medium farms across Russia to do this, and to raise the incomes and livelihoods of farm families while improving the sustainability of natural resources. For example, digital technologies can be used to connect smaller producers to markets at no or lower cost, thus boosting their opportunities to be included in value chains. This is important because small producers could have access to more income opportunities, generate more jobs in rural areas, and improve the livelihoods of a considerable number of rural inhabitants.

This note provides an overview of the potential for digital agriculture in Russia. It surveys examples of the use of digital technologies on Russian farms today—a phenomenon that occurs for the most part in Russia's very large agro-enterprises. It examines efforts (often by the private sector) in other countries to help poorer and smaller farms adopt and take advantage of digital technologies. Finally, it indicates areas of further follow-on work that will be needed to identify measures that could be considered to expand the adoption of digital technologies in Russian agriculture—including to small farms and small agribusiness enterprises.

Technology adoption and the transformation of agriculture

Technology adoption in agriculture, and the benefits of such adoption that accrue to farmers, are topics that have been extensively studied. Often focused on the adoption of several specific farm-level technologies—such as high-yielding variety (HYV) seeds, fertilizers, irrigation schemes, and so on—the literature has developed explanations as to why farmers do (or do not) adopt technology. Factors that affect technology adoption include farmers' wealth and education level, their access to information, and the availability of technology (Feder, Just, and Zilberman 1982; Fuglie and Kascak 2001). More recently the adoption of digital technologies and the benefits that are consequently accruing to farmers are being investigated more vigorously.

The adoption of digital technologies in agriculture is uneven in scale and scope. Commercial, large-scale agriculture in the developed world, including large agri-enterprises in Russia, has been adopting and adapting digital technologies for some time now. Specifically, these include so-called precision technologies in agriculture. An accumulation of evidence indicates that precision technologies reduce production costs and improve yields, and that over time these technologies positively impact the bottom lines of farms and agri-enterprises (Schimmelpfennig 2016). Mounting evidence shows that such precision technologies are benefiting Russian agri-holdings, which increasingly adopt them as local content and software providers and equipment manufacturers expand the technologies to Russia (Ministry of Agriculture of the Russian Federation 2018).[2] However, precision technologies are most effective when they are already combined with modern agricultural technologies, such as HYV seeds, better fertilizer and pesticides, and efficient farm management. Therefore such precision technologies work best when the farms are large and sophisticated, have access to capital, and have a specialized labor force that can use the technology and apply it to the benefit of the farm. Precision technologies are also complex, knowledge-intensive, and expensive to introduce. Small and medium farmers (such as individual farmers and household farmers in Russia) rarely, if ever, have access to or can utilize precision technologies.

Perhaps this is why agriculture is behind other sectors in adopting digital technologies. Despite all the technological advances registered by the agriculture sector in the digital economy, the sector remains far behind others in adopting digital technologies, as identified by a recent study by McKinsey (Laczkowski and others 2018).

Experiences from several countries show that farmers do not always use digital applications, but when they do use these applications they consistently benefit from them. Such applications range from checking the weather on a mobile phone and making payments and transferring money through mobile applications to using sophisticated crop forecasting and mapping tools. Although the literature on the adoption of mobile phone applications for agriculture is not as extensive as the literature on discrete agricultural technologies, there are several important takeaways from the current research:

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[2] See also (1) Точное животноводство: состояние и перспективы / Е. В. Труфляк. – Краснодар: КубГАУ, 2018. – 46 с.;
(2) Точное земледелие: состояние и перспективы / Е. В. Труфляк, Н. Ю. Курченко, А. С. Креймер. – Краснодар : КубГАУ, 2018. – 27 с.;
and (3) https://kubsau.ru/science/foresight/publications/.

- ✓ Benefits from mobile phone applications, but not their adoption rate, are positively correlated with the wealth and education of farmers—that is, as is the case for discrete technology adoption (HYV seeds, for example), farmers with more years of schooling and more assets are likely to benefit more from mobile phone applications (Cole and Fernando 2012).

- ✓ Digital applications can reduce and eliminate temporal and spatial problems associated with discrete agricultural technology adoption. For example, access to mobile phone– based advisory services or information on agricultural technology is more continuous than agricultural advisory services, which in most instances is one-time and discrete. As a result, if a new seed variety is available, farmers who use mobile technologies to learn about the seed variety are more likely to benefit more than farmers who rely on the advice from traditional extension agents (Aker 2011).

- ✓ Farmers' literacy levels are not associated with mobile technology adoption (Aker and Mbiti 2010); in other words, the research rejects the widely held assumption that farmers do not have enough skills to apply and benefit from digital applications.

The question is whether and how digital technologies can transform agriculture in the way other discrete technologies have transformed the sector, for instance, during Green Revolution. It is unlikely that digital technologies alone would result in another Green Revolution. As a matter of fact, the next Green Revolution would be difficult to achieve given the low level of public spending in agricultural research in the United States and Europe and the continuing lack of efficiencies in agricultural research systems of Russia, Brazil, China, and other countries.

What digital technologies can do, however, is augment the potential of existing agricultural technologies by reducing input requirements, advancing farm management through improved precision of farming, better connecting farmers with markets, reducing information asymmetries, and making better inputs widely available.

In what way do digital technologies transform agriculture? They first disrupt labor requirements. Evidence shows that labor costs are reduced in large farms when digital precision technologies are being used. Because of their structure, food value chains have the capacity to absorb agricultural labor, and evidence shows that the quality of jobs increases when farmers use digital technology. For example, farmers who use digital means to connect to markets transition from being just farmers to becoming famers-processors-packers-distributors-retailers.

Second, digital technologies increase the value of agricultural production. Improved access to information and better access to markets helps produce more customized products demanded by consumers, and therefore helps to generate and keep more value at farm level. Third, they reduce costs. The challenge is to promote their wide adoption and scaling up to broader categories of farmers, especially those who would benefit more from improved incomes.

According to the key takeaways from the digital agriculture conference that took place in Moscow on May 15, 2018, in the current state of Russian agriculture technology development the following phenomena require most attention:

- ✓ Technology development in general has enabled a wide range of technology start-ups and established firms entering the digital agriculture marketplace, from soil assessment services and farm data analytics to unmanned vehicles for automation. However, these solutions work mostly in siloes, prohibiting wider access by the majority of agriculture practitioners because of technical barriers and financial constraints, the results of incompatible standards between digital infrastructure or the lack thereof, and the non-commercialization of these technologies.

- ✓ Demand in the digital agriculture space is neither well defined nor surveyed. ICT solution providers and technology companies have the backend infrastructure but lack the expertise to identify the gaps where digital technology can generate the most value addition. Currently, from a supply-chain perspective, digital technology has been most developed and replicated toward one end of the spectrum, directly facing consumers with delivery of ready-made food. The application of technologies for input supply, machinery, and agronomical data modeling remains comparatively rare; only a few early start-ups have explored technology for agro-product transaction and export. An ecosystem approach to constructing an enabling environment to provide tailored applications requires all IT specialists, farmers, telecommunication-mobile operator providers, and the public sectors to contribute to the hardware, software, and content-specific application to maximize the benefit digital technologies can bring to agriculture.

- ✓ Open data remain the main bottleneck for digital technology to proliferate in the sector. Specifically, data quality; data security; and the method used to collect, manage, and analyze require further progress and the building of the data science arsenal. Leveraging the regulatory mechanism will be crucial to building and scaling up the use of digital technology in agriculture.

- ✓ The industry lacks qualified IT specialists to take advantage of the availability of big data analytics: one out of every 1,000 employees is an IT specialist (Ministry of Agriculture of the Russian Federation 2018). In addition, the current education system does not provide sufficient agribusiness and other relevant training, relegating the responsibility to industry alone.

Organization of the report and typology of digital tools for agriculture

The analyses and discussions of this report are based on a review of global and Russian tools, technologies, and services for digital agriculture. Our team reviewed various reports and websites and interviewed firms, experts, farmers, and developers to identify technologies that are most common in agriculture globally and are most relevant and applicable for Russian agriculture. Our objective was to identify those technologies and tools that either have potential for use by small and medium farmers or are already being used predominantly by small and medium farmers. In this report, we did not attempt to analyze implications of our findings for public policy, leaving that exercise for future work.

Digital tools and technologies help deal with information asymmetries and make information more freely and speedily available to users. Because of the inherent public good properties of information, there are a variety of roles for the public sector in providing and regulating the use of digital tools in agriculture. In exploring how digital tools are used in agriculture, and in exploring the role for the public sector in this regard, it is useful to consider a typology of the functions that digital tools can provide in the sector. Here we consider two broad categories of the functions of digital tools in agriculture. The first category is about functions related to more effective agricultural knowledge and information systems:

- ✓ Capturing information from farms and agribusiness
- ✓ Managing information
- ✓ Making information available to farms and agribusiness

The second category is about functions that enable market access and provide market opportunities. It combines two typologies of technologies:

- ✓ Linking market participants
- ✓ Facilitating digital transactions

The five elements of the typology introduced immediately above represent five basic functions that digital tools can facilitate in the agriculture and agribusiness sectors (table 1). By improving the ways in which these functions operate (making them faster, more effective, less expensive, more accessible, available to more people, more convenient, more user friendly, and so on), digital tools have the potential to improve the performance of the agricultural and agribusiness sectors. For example, by making hyperlocal information about soil moisture or crop diseases more easily available, digital tools can contribute virtually instantaneously to on-farm productivity.

For some farms and agribusinesses (particularly larger firms), using digital tools to facilitate the above functions is something that they have been able to do on their own. However, there are elements of public goods in the provision of the five functions identified above—especially for small farms. By examining each function—and by examining the roles and responsibilities and incentives of actors at each level of aggregation (that is, at the farm level, at the local government level, at the national government level, at the agribusiness level, and so on) for each function, it is possible to identify the role of the public sector. Identifying this role is particularly useful because it applies to giving small and poorer farmers access to each of the functions in a more efficient manner than would be the case without public sector intervention. Careful examination and articulation of such roles is beyond the scope of the present report, but would be a valuable exercise in further work as an input into strategic planning for agricultural and rural development (in Russia and beyond).

How should this report be read? The two groups described above form the two main sections that follow. The two sections categorize typologies of digital tools and services for agriculture with a view to expanding the benefits of digital technologies to small and medium farmers. Within each part we probe each typology and present examples of typical technological solutions from Russia and around the world. In addition, each part contains a case study that describes a practical example of public policy intervention that can help expand the benefit of digital technology in the agriculture sector, especially for small and medium farms. Part I presents a case study on digitizing soil information systems. Part II presents a case study on promoting the interoperability of IoT platforms and their benefits for agriculture. The report concludes with a summary of proposed areas for future research and recommendations.

Table 1. Mapping typologies of digital tools on an agri-food value chain

Value Chain & Technology Typology	Farm Production	Inputs	Logistics/ Transport	Financial Services	Processing	Market
Agriculture Knowledge and Information System						
Capturing information from farms and agribusiness	AgroDroneGroup* AgrivitaFarm* GeoScan* Panasonic Russia* RoboProb* R-Sept* Trimble*	Olam	n.a.	n.a.	AgroTerra* Smart4Agro*	n.a.
Managing information	aWhere ExactFarming*	n.a.	n.a.	n.a.	n.a.	n.a.
Making information available to farms and agribusiness	Gamaya	n.a.	n.a.	n.a.	n.a.	Farmerline
Market Access and Market Opportunities						
Linking market participants	Connected Farmer	n.a.	Hello Tractor Twiga Food	n.a.	n.a.	Kaluga Agribusiness Development Agency*
Facilitating digital transactions	n.a.	n.a.	DigiFarm	TakeWing* Tarfin Umati Capital	n.a.	n.a.

Note: * Russian firms; n.a. = not applicable.

PART I. Digital tools activate agricultural knowledge and information systems

Steady advances in agricultural knowledge have profound implications for agriculture and agribusiness. Advances in knowledge about crop and livestock genetics can raise on-farm productivity and improve the quality of farm products. Advances in knowledge about how weather and soil characteristics affect crops can also raise on-farm productivity and improve the quality of farm products. Advances in knowledge about mechanization can improve labor productivity on farms and in agribusinesses. Such advances in knowledge can be transformative for the agriculture sector.

But developing agricultural knowledge depends on the capture and use of information (data about on-farm trials, weather data, information about soil characteristics and quality, and so on). Furthermore, putting agricultural knowledge to use depends on being able to transmit information from knowledge sources to the level of the farm and agribusiness. Digital tools are making it possible to capture information at every level, to manage and analyze it to create knowledge, and to send knowledge-based information back to users at the farm and agribusiness level. This section discusses each of these steps and presents examples from Russia and from other parts of the world.

Capturing information from farms and agribusiness

Vastly more information about what is happening on farms and in agribusiness is available now than ever before—and this information is increasingly available in digital form on a more timely basis, at less cost, and in more easily usable form. One emerging source of information is remote sensing. Satellites are collecting field-level information about crop cover, crop conditions, crop health, soil conditions, weather conditions, and crop yield estimations, and are making all of this information available to farmers as well as to agribusiness and to other industry observers (including ministries of agriculture). Drones are capturing even more detailed information at the field level, including monitoring for and identifying crop diseases, monitoring soil moisture, and providing images for use in establishing property boundaries and for many other uses.

Another emerging source of information about what is happening at the farm level falls under the category of the IoT. In many places, on-the-ground sensors continuously relay information to farmers about water usage, soil moisture, field (or greenhouse) temperature, and other important production variables. This allows rapid response to current conditions—adjusting irrigation pumping and turning on or off water and heaters in greenhouses, to name just a few. Strategically placed weather ground stations relay critical, detailed, and location-specific weather information to weather information services. Sensors on farm machinery record the location of the machinery as well as operational and performance data.

These and other digital tools are making the flow of information and communication from farmers and their advisors to public program officers simple and systematic—not only to farmers themselves, but also to public agencies. For farmers, such information enables better planning and decision-making, thus unlocking possibilities for improved productivity and profitability. For public agencies, these tools allow the collection of farm-level data for the purposes of monitoring and evaluation with respect to the outcomes of public programs; they also allow feedback by users and other stakeholders on the performance of public policies and programs.

Managing information

Digital tools are transforming the way that knowledge and information about agriculture are managed at every level.

At the level of farms and agribusinesses, the vast increase in the availability of knowledge and information, together with the ability to manage and utilize that knowledge and information, is an important factor in substantial growth in productivity and profitability. Digital farm management tools are making it possible for farmers themselves to use detailed information about production variables (such as weather, field conditions, milk quality, feed consumption by livestock, market prices, and so on) to formulate and evaluate production options and to make real-time and longer-term decisions to optimize profit and productivity.

At the aggregate level (such as at ministries of agriculture), advances in digital tools are making it possible for public programs, services, and policies in support of the agriculture sector to be more efficient, relevant, evidence-based, tailored and targeted, transparent and monitorable, and generally more effective than ever before. One of the most basic agricultural information functions of the public sector lies in the area of agricultural statistics. Historically, public agricultural statistics systems in many countries have often been clumsy to use and not very reliable. A digital national agricultural statistics system (systematically linked to the national statistics authority) can overcome earlier obstacles to ensure easy storage, updating, and retrieval of agricultural data; accept and systematically collect on-farm and market data from remote sensing, market transactions, and other digital data collection sources; facilitate the dissemination, manipulation, and analysis of agricultural data; and facilitate access to farm-level and aggregate sectoral information for the purposes of analysis.

Making information available to farms and agribusinesses

More than ever before, digital tools and services make it possible for relevant and detailed information and knowledge to be made available directly to farmers and to other stakeholders in the agriculture sector. Such digital services can be either “push” or “pull” in nature. On the one hand, such services can allow advisors to push information directly to farmers when experts recommend that farmers consider using it for their own crops and conditions—perhaps sending information to their phones or to other locally available digital devices. A common example of this in Russia can be found on large agri-holdings. For these farming companies, detailed technical instructions can be relayed from agri-holding headquarters directly to staff in fields. Similarly, precise information and instructions can be sent directly from satellites to farm workers and farm machinery in real time as they work with crops and livestock in fields and barns—adapting seeding rates, fertilization, feed mixes, and so forth on the go. This is precision agriculture.

On the other hand, such digital information services can be pull in nature—allowing farmers to pull information they need, to get answers to questions they have, and to give feedback regarding what more they need to know. Farmers and their partners can get instant access (in digital form) to information about markets and prices, analysis of possible disease threats in their fields together with expert advice on how to deal with such problems, weather data and location-specific forecasts, and so on. This allows effective communication between farm and agribusiness enterprises—helping farmers to optimize the precision and efficiency of their practices and activities as well as helping them to mitigate risks.

Practical examples of the use of digital technologies to activate agricultural knowledge and information systems

Digital technologies are used for agricultural knowledge and information systems in Russia and in the rest of the world. This section provides examples from each in turn.

Russian examples of agricultural knowledge and information systems

In Russia, domestic digital technology development in managing agriculture data and operations is still in a nascent stage. Technology serving agro-holdings to medium-size farms remains the main type of agri-tech in the market for a variety of reasons. Such technology ranges from advanced devices capturing real-time data through Global Positioning System (GPS) technology, satellites, and sensors for optimal farm operation management to unmanned vehicles for automation. For small and medium farms, the same goal of increased productivity with higher efficiency requires tailored approaches and may also require (at least initially) targeted public support. A number of homegrown innovations have witnessed early results serving the market, although they mainly serve medium and large-scale farms (1,000 hectares and larger) rather than small farms. In this section, a number of examples are presented of digital tools that are currently being used on farms and by agribusinesses in Russia.

Farm management

A cloud-based farm data management platform, ExactFarming, collects and makes sense of farm operation data including pesticide usage, farm vehicle operation, and vegetation status through satellite images to inform farm decision-making (figure 1).[3] The platform also disseminates data including weather and soil (ability to disseminate soil data is forthcoming) tailoring to specific account holder geographic conditions. Through partnership with MAP (a charitable organization that provides medicines and health supplies to people in need),[4] as well as local weather field stations, ExactFarming extracts weather data onto its software platform for multi-source data integration; and with Agrosignal,[5] a Russian software company, ExactFarming monitors farm vehicle location, tasks, and performance, such as completion rate and speed, through GPS for economic planning.

With farm data captured, ExactFarming is able to pursue several initiatives to help facilitate client

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[3] For further information about ExactFarming see https://www.exactfarming.com/en/.

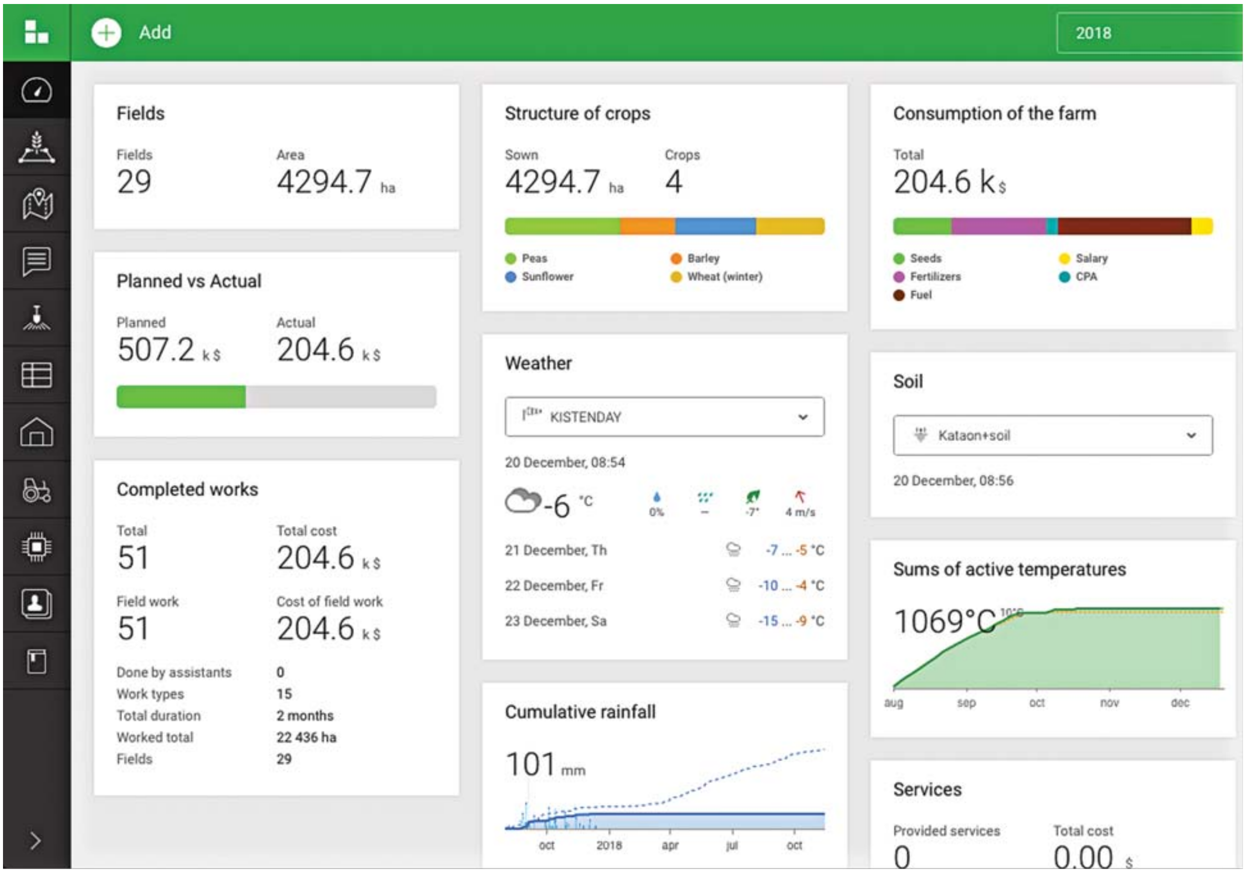
[4] Information about MAP can be found at https://www.map.org/.

[5] Information about Agrosignal can be found at https://i3connect.com/company/agrosignal.

business by working with agro-dealers to bridge gaps throughout the supply chains, and with financial institutions as well as agro-holding companies to extend credit to small and medium farms. The foundation for effectively capitalizing on the data-informed decision tools so that they become engines for economic growth is a shared understanding of the technology, its analytics, and its implications; equally important are the organizational support and leadership needed to adjust and restructure the current system to pilot and course correct.

Among the 5,000 accounts on the platform, the majority of the farmlands under management are above 1,000 hectares; around 30 percent of the accounts manage farms of less than 1,000 hectares. ExactFarming states that the key to increasing technology uptake among small and medium farms lies in the trust between users and the relevant technology in achieving the proclaimed goals, including better decision making and timely advice for improved productivity. Price is not the issue: the software fee is usually a neglectable proportion of the overall farm expenses: 50 rubles per hectare per year compared to 12,000 to 20,000 rubles. To encourage technology adoption, field demonstration remains the most effective and

Figure 1. ExactFarming online platform: Dashboard



Fields
Fields 29
Area 4294.7 ha

Planned vs Actual
Planned 507.2 k$
Actual 204.6 k$

Completed works
Total 51
Total cost 204.6 k$
Field work 51
Cost of field work 204.6 k$
Done by assistants 0
Work types 15
Total duration 2 months
Worked total 22 436 ha
Fields 29

Structure of crops
Sown 4294.7 ha
Crops 4

Weather
KISTENDAY
20 December, 08:54
-6 °C

21 December, Th -7 ... -5 °C
22 December, Fr -10 ... -4 °C
23 December, Sa -15 ... -9 °C

Cumulative rainfall
101 mm

Consumption of the farm
Total 204.6 k$

Soil
Kataon+soil
20 December, 08:56

Sums of active temperatures
1069°C

Services
Provided services 0
Total cost 0.00 $

Source: ExactFarming screenshot.

convincing way to communicate its economic benefit for the business.

The use of drones

Within the Russian agri-tech spectrum, the development of unmanned aerial vehicles (UAVs), commonly known as drones, for crop and soil quality monitor is comparatively mature. Several products and services have undergone pilots and are moving on to mass commercialization. AgroDroneGroup and GeoScan employ drones equipped with cameras to conduct aerial surveys.[6] These surveys are capable of obtaining, among other things, orthophotos (aerial photographs that have been geometrically modified to present a uniform scale), data for normalized difference vegetation index (NDVI) mapping, snapshots of crop conditions and levels of germination, and information about water erosion.

As opposed to standard satellite images of 15–30 meters per pixel resolution, GeoScan UAV provides images of 5 centimeters resolution, covering farm sizes from 30,000 hectares to 100,000 hectares. These images—turned into digital terrain models (DTM) and digital elevation models (DEM) through software data processing, analysis, and visualization—inform farms of the state of the land and the direction of soil cultivation, monitor diseases and yield, and model for floods.

AgroDroneGroup, a company that develops and manufactures UAV-based solutions, leverages hyperspectral technology (which can provide detailed information on a leaf, for example, which is useful for identifying diseases) to obtain 10 times more data than NDVI can provide. With this technology, the company builds a database with which to make farm work recommendations by processing real-time data with a proprietary algorithm. Beyond the in-house database, AgroDroneGroup also recognizes the benefits of open data from other business entities to inform its analytics.

In order to widely disseminate drone services to farms, AgroDroneGroup is piloting its services under the sharing economy model to “uberize” drones for agriculture work on demand. The pilot drew thousands of interested drone pilots to be part of the tryout. Despite its initial success, the key for such service would require enhanced agriculture knowledge on the pilots’ end and an improved communication channel to best disseminate data in useful form in a timely manner. Currently the main channels of communication are mobile phone and e-mail.

Robotic soil testing and mapping

In an attempt to complement current soil test methods, RoboProb designs a robotic platform for automated soil sampling to minimize human error and increase efficiency.[7] The platform is a self-propelled complex that can work as a stand-alone device or as a trailing unit on any transport vehicle.

The automation service of RoboProb soil sampling, labeling, and packaging is able to save farm labor requirements so it can decrease from a team of five to

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[6] Information about AgroDroneGroup is available at
http://agrodronegroup.ru/ (in Russian); information about GeoScan can be found at https://www.geoscan.aero/en/about.

[7] Information about RoboProb can be found at https://www.roboprob.com/ (in Russian).

a one-man team that will suffice for up to 36 pieces of sampling in one attempt. The robotic complex leverages ground-based methods to mitigate the assessment errors that exist between the device and the soil, to which remote sensing is highly prone. While positioning accuracy to up to 1 meter, the device is able to move at a speed of up to 30 kilometers per hour.

Once the tasks are completed, the data extracted from the farm are compiled into an electronic soil map that details the fertilizer application of each plot.

The above examples demonstrate the promise of digital solutions development for Russian agriculture to closely manage farmland with an evidence-based approach. Financial support is crucial to spurring the growth of the agri-tech space founded on evidence-based research rather than trial and error, thereby refining and proving product viability, market fit, and value proposition to a wide range of clients.

Encouraging entrepreneurship and agri-tech start-ups

Support for the agri-tech landscape in Russia currently is concentrated at the federal level. Initiatives such as the Internet Initiative Development Fund (IIDF) and the Skolkovo Foundation and Skolkovo Venture, as well as state-owned nonprofits including the Foundation for the Assistance to Small Innovative Enterprise (FASIE), are building the technology ecosystem to assist ideas turn into products and facilitate peer learning by providing a dedicated space for brainstorming and dialogue. On the rise are the interest and appetite of venture capital and private equity in guiding agri-tech start-ups to understand market needs and access funds.

The shared characteristics of this support are brought together through incubator and accelerator programs, which convene mentors and industry experts to work with tech entrepreneurs on their products and business plans; through office and lab infrastructure, which facilitate business and product development; and through tax benefits and accessing a wide range sources of finance through showcase events as well as business competition.

In examining the current landscape of Russian agri-tech development and its challenges, Managing Partner for Agri-Tech at Skolkovo Venture, Pavel Danilov, and CEO of AVG Capital Partners, Roman Trofimov, point to the significance of a clear grasp of market orientation and the ability of tech entrepreneurs to identify their critical needs as well as their own niche in serving specific segments. Because of the dynamic technology adoption trajectory, the capacity required to develop appropriate technology, and the time necessary for such development, the market now sees a fragmentation of available services, leaving much of the opportunity for crop and high-value product uncaptured. Additionally, the financing system has not yet been able to support the overall development. The logical exit plan for a technology start-up—selling the technology to a big corporation—is not fully viable because the institutions are not ready to acquire.

With the majority of funding from the public sector going to subsidies, the limited proven sustainability and benefits for small farms lead the private sector to explore ways to channel financial resources into an alternative public-private partnership (PPP). By scouting high-potential companies with fund managers of agriculture expertise, industry experts and business veterans within the fund network can provide strategic advice to the companies as well as assess their investment readiness. Liaising with diverse actors throughout the value chain on behalf of the agri-tech community, an alternative PPP has the potential to consolidate a broad array of funding for companies at various stages of maturity or investment readiness as the return objective and risk appetite vary. Funding from venture capital, private equity, public finance, and development finance will contribute to developing a solid tech ecosystem with flexible financing options for businesses to achieve their objectives.

Global examples of agricultural knowledge and information systems

Internationally, the use of digital technology to create and maintain agriculture information systems occurs primarily at the national or the supranational level of aggregation—and in some cases is championed by the private sector. Technology deployment to obtain, extract, and manage agriculture information from and to farms is economically viable only on a large scale. The Internet of Food and Farm 2020 (IoF2020), a mega IoT pilot project in agriculture co-funded by the European Commission (EC), aims to convene key private, public, and not-for-profit stakeholders throughout the value chain to validate technology choices: from timely and precise farm data through IoT for productivity enhancement and traceability, and from GPS and sensors for livestock movement monitoring, to machine learning technology for dairy quality assurance. Apart from the technology, IoF2020 seeks to identify user needs and concerns, including system interoperability, data security, and localization; to structure optimal business models and processes; and to provide agri-tech entrepreneurs with relevant data and market entry support.

Along with Wageningen University Research (WUR) in the Netherlands, the 70 partners of IoF2020 from 14 countries focus on five work pillars: project management, trial management, IoT integration and capabilities, business support, and ecosystem development; and on five agriculture value chains: arable crops, dairy, fruits, vegetables, and meat. Notably, among the 38 private sector partners, 24 are small and medium enterprises (SMEs). The project emphasizes actively involving end users, the farmers, to co-design and to provide feedback on user experience.

Launched in the first and second quarters of 2017, IoF2020 has developed 19 cases to date with various areas of progress. Within-field management zoning, an IoT deployment on potato farming, aims to develop detailed soil maps, input a variable rate application map service, and facilitate automation and machine communication. The setup probes field soil moisture, soil organic matter, and mineral composition to create a soil map from which the variation rate application map is developed through a geographic information system (GIS) platform. On the software front, the system can translate crop management tasks into machine tasks, allowing for automation by aligning machine interfaces. The pilot program seeks to reach higher yield and quality with lower production cost by improving farm management, serving small farms of 50 to 200 hectares.

Another application of IoT on farms is illustrated by utilizing precision crop management to monitor wheat crops' real-time nutrition status through both ground and satellite images. With the data at hand, the project seeks to assist farms with water and nitrogen application through digital task management and automation of the application process.

Another category of the use of IoT on farms has to do with establishing real-time communication between farm machines. Machinery interoperability is achieved by standardizing and aligning protocols, vocabulary, and semantics. Such efforts will enable efficient data sharing among farm machines. By working with farm machine manufacturers and software companies, the project seeks to facilitate data transmission between field machinery and farm management information systems (FMIS) both on- and offline and through application programming interface (API) harmonization, thereby making real-time analysis of diverse data formats possible for precision farming.

Using big data and local data for crop management

An example of a private sector initiative to make detailed and local information available directly to farmers and agribusiness is the platform developed by a U.S.-based firm called aWhere.[8] aWhere operates in a global-scale agronomic modeling environment with immense processing capacity that collects over 7 billion points of data every day to create unprecedented visibility and insight across the agricultural soils. aWhere's hyperlocal agricultural information and insight support precision agriculture. Using proprietary blending and predictive modeling, aWhere provides field-level observations and forecasts weather, growth stages, and pest and disease risk. aWhere's information platform and tools offer the possibility of transforming the way agricultural decisions are made by grounding them in data and analytical insight that have never existed before.

Remote sensing imagery and crop management

The majority of worldwide examples of agriculture information technology deployment rely on the effect of economics of scale, thereby starting with large-scale farms. Gamaya,[9] a Swiss agri-tech company employing drones equipped with hyperspectral cameras to collect farm images for precision farming, entered their first market in Brazil. The hyperspectral technology is able to detect the state of the crops and also the rate of the crop development by measuring the light reflected by the plants. Complemented by information gathered through other sources of data, including satellite and sensors, the data are then interpreted by Gamaya's in-house software using machine learning and artificial intelligence (AI), providing detailed insights and action plans for farms through its cloud-based platform.

In addition to the ability to extract and act upon the data analytics derived, Gamaya plans to scale up the work to create a global crop database with crop- and region-specific intelligence. With the help of hyperspectral imaging technology, Gamaya started with soy and cane cultivation solutions to identify weed infestation for adequate herbicide applications and to detect nutrient levels at various crop stages, as well as to map soil erosion and estimate yield.

Exploring public support for investments in on-farm use of digital technologies

To adopt technologies as advanced as the hyperspectral imaging used by Gamaya, the upfront

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[8] Further details about aWhere are available at http://www.awhere.com/.

[9] Further information about Gamaya can be found at https://gamaya.com/.

investment required often proves prohibitive for small and even medium farms. The company is exploring approaches to overcome such challenges with the model of flipping technology ownership: instead of owning the technology on the farm end, the public sector can bear the upfront cost of installment, reacting to and leveraging the data captured for program design, tailored extension, and advisory services delivery. The key is to make data available to relevant stakeholders beyond the financial and technical constraints that often hinder small farms' access to necessary information. Whether such an approach will be a game changer that proves viable depends on a collective effort of the public and private sectors and civil society to devise a mechanism that accounts for the overall technological capability, data security, and shared cost as well as revenue and technical assistance for end users to leverage the farm and market intelligence at their own command.

Private sector support for on-farm adoption of digital technologies

While it is appropriate for the public sector to support some aspects of the development and adoption of digital tools and approaches, for many applications, the private sector also plays a role in supporting adoption by farmers. Traditional private sector entities throughout the agriculture value chain also invest in bringing digital technology to small and medium farms. The global input company Olam employs the in-house Olam Farmer Information System (OFIS) to obtain farm-gate level data, deliver training modules, and record first-mile business transactions.[10] As of 2017 Q2, the system had registered 100,000 farmers in 21 countries across multiple continents.

OFIS helps the conglomerate manage smallholding clients around the world, and in return makes specific operation design and services back to the farm possible. With a mobile device, OFIS records GPS data for logistics, farm location, and input transactions; it also provides a revisable survey model to gather relevant farm data. Furthermore, the system performs decision-making tasks by analyzing statistical data and locating key social infrastructure information and farmer profiles to inform user actions such as farm training design or business risk mitigation.

From the farm's/cooperative's perspective, the data captured by OFIS help inform the company so it can deliver tailored modules on extension services for improved agriculture practices. In addition, payment can now be processed online directly to farmers, thereby expanding their access to financial services.

CASE STUDY: Digital tools and soil information systems

Over 150 years ago, Russian Professor Vasiliy Dokuchaev established agricultural experimental work through morphological and genetic soil science as a separate branch of knowledge. Russia introduced soil science to the world and became the first country to start taking care of and restoring soil cover at the country level. Russia has a strong tradition of education and research in the area of soil science. However, after the 1990s, the number

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[10] Further details about Olam are available at http://olamgroup.com/.

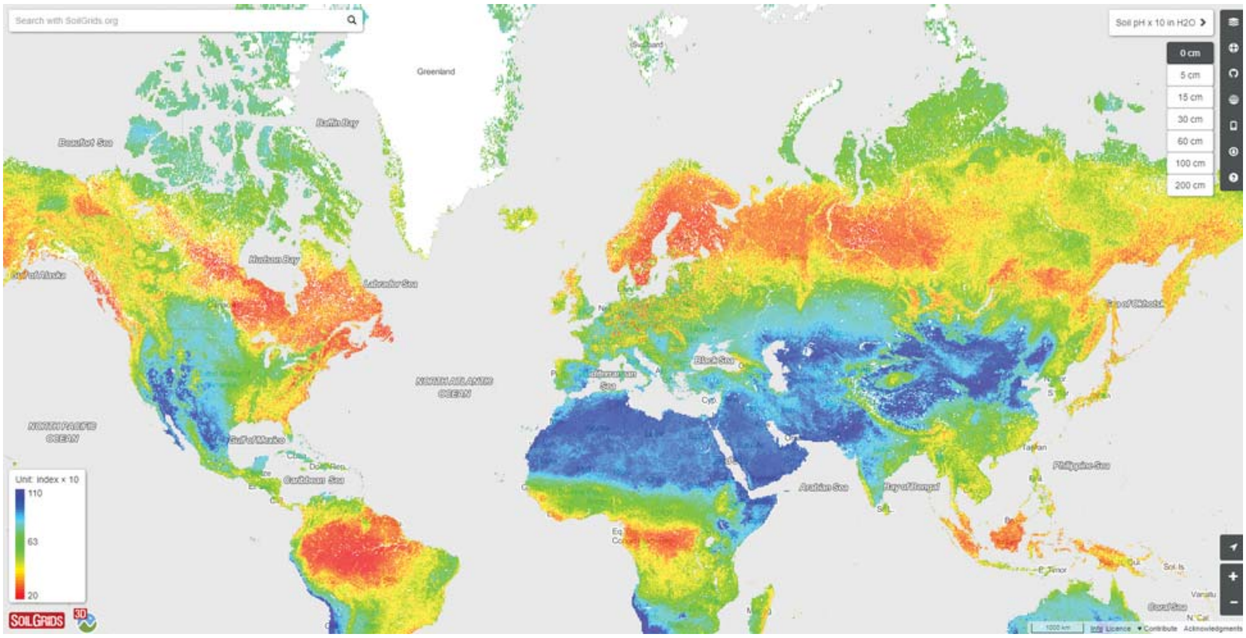
of organizations collecting soil data decreased and soil science lost its importance. In this section we discuss international experience at collecting soil data; the current situation in collecting data in Russia and data availability; barriers to making data available (for example, national security, poor infrastructure, lack of a unified approach); and the benefits to farmers of using digital tools while collecting soil data.

Information on the state of soils and soil cover is fundamental when taking decisions about combating desertification, halting and reversing land degradation, and improving agricultural land quality. These all contribute to sustainable agriculture as well as to strengthening food security. Achieving these goals requires the availability of detailed and up-to-date environmental information, including soil information. Creation of digital soil databases and the development of digital soil mapping methods are actively being pursued in order to reduce the gap between the demand for soil data and their availability.

On a global level, the International Soil Reference and Information Centre (ISRIC) has created the SoilGrids soil information system (Hengl and others 2017). This system provides public access to global maps, with a resolution of 250 meters, of a number of indicators of soil properties, including organic carbon, bulk density, cation exchange capacity (CEC), pH, soil texture fractions and coarse fragments, and depth of the parent material. The ISRIC also provides access to the classes of the World Reference Base for Soil Resources (WRB). The SoilGrids system is constantly updated.

SoilGrids data can be uploaded under the Open Database License (ODbL). Access to SoilGrids maps is provided via a soil web-mapping portal at SoilGrids.org (figure 2); through a Web Coverage

Figure 2. Global digital map of soil PH



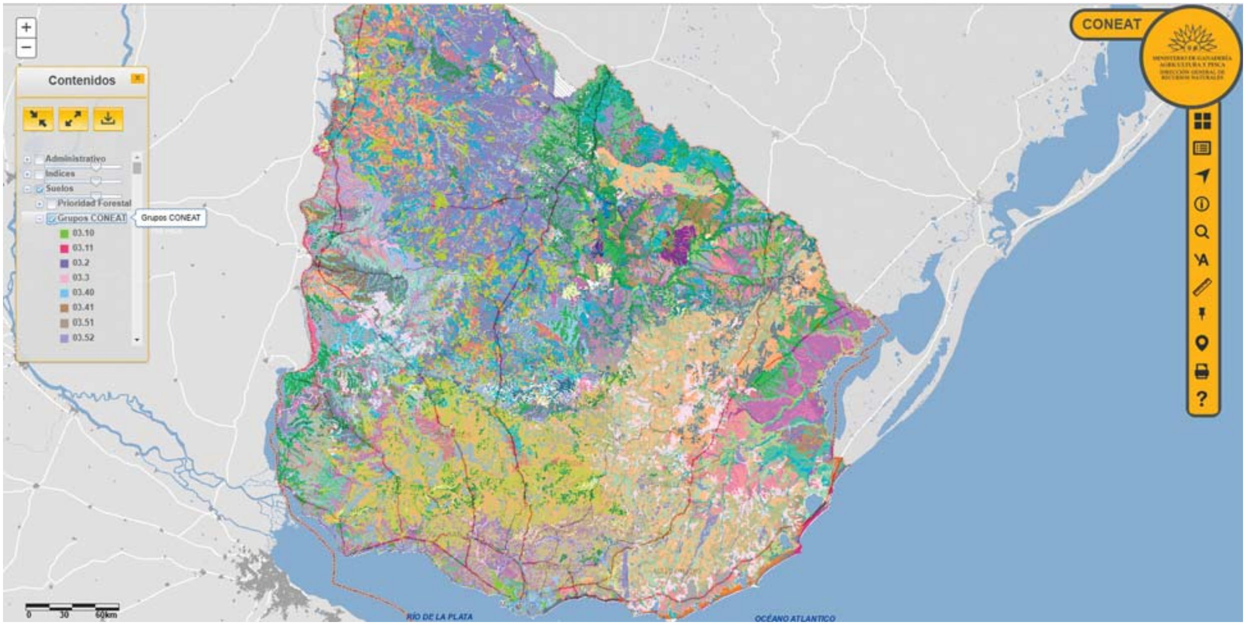
Source: soilgrids.org, June 6, 2018.

Service; and via the SoilInfo App (Hengl and others 2017). Constant data updating and detailing helps to create more accurate global models—for example, global gridded crop models (GGCMs)—that facilitate reliable assessments of the impact of climate change and land degradation on food production (Folberth and others 2016).

On a country level, in the United States, the collection, storage, management, and dissemination of information on the soil cover survey are the responsibility of the Natural Resources Conservation Service (NRCS), an agency of the United States Department of Agriculture (USDA). For various purposes, the NRCS has created soil-geographical databases, such as the Soil Survey Geographic Database (SSURGO) and the State Soil Geographic Database (STATSGO). The SSURGO standardized digital geographic database contains information in the form of digital maps at scales from 1:63,360 to 1:12,000 and provides the most detailed level of the information. This database was developed mainly for planning and managing natural resources at local and regional levels: farms and ranches, settlements, and districts. It serves as a source for identifying eroded areas and developing methods for erosion control, and for determining the potential for land use. The STATSGO database (at a scale of 1:250,000) provides less detailed information, which is necessary to solve problems at the state level. The NRCS operates with more than 20,000 U.S. soil profiles.[11]

Another example of soil data use at the state level is the Department of Agriculture of Uruguay, which

Figure 3. Detailed map from the CONEAT index



Source: The Ministry of Agriculture of Uruguay, available at http://web.renare.gub.uy/js/visores/coneat/..

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[11] Raster data from SSURGO and STATSGO2 are accessible and can be downloaded via the Web Soil Survey (WSS) at https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

also provides public access to soil information. Soil types are classified according to their productivity and measured by the index called CONEAT.[12] The CONEAT index of a property also correlates with the price of the land and makes the market transparent: it is easy to compare properties. An online detailed map shows specific properties as types of soil in different colors (figure 3), the productivity index of each type of soil, and the average CONEAT index for the each land use pattern.

In Europe, the main source of soil data is the European Soil Database (ESDB). It includes the territory of Belarus, Moldova, Russia, and Ukraine (Stolbovoy and others 2001).[13] In addition, soil information is included in the Infrastructure for Spatial Information in Europe (INSPIRE) as one of 34 themes. INSPIRE has been a directive of the European Union (EU) since May 15, 2007. It obliges all EU members to create an infrastructure of spatial data on the Internet to facilitate the standardized exchange of geographical information between countries. Different types of spatial data that are provided by different organizations are used simultaneously and combined into layers in different user applications. It is believed that ensuring the wide availability of such information will allow many industries and government institutions to improve operating efficiency and reduce costs. The project implementation will end in 2019. The benefits from efficiency gains alone are expected to be in the order of 1 billion Euros per year (INSPIRE 2003).

Comparing the situation in Europe with collecting soil information in Russia with given examples, it is evident that the national soil database of Russia is in its infancy. There is no clear content in Russia's soil resource management policy (Shoba and others 2008). The result is a lack of a unified approach and objective in soil inventory and the creation of soil-geographical databases: work is being undertaken by different teams with different methods.

It is important to note that in Soviet times such a state system existed. When that system was functioning, large-scale mapping of all agricultural lands of the country was carried out several times. Based on the large-scale maps, a series of medium-scale soil maps of the regions was created, as well as several soil maps for the whole country. Hard copies of soil maps are now part of the soil data center of the V.V. Dokuchaev Soil Science Institute, which contains more than 20,000 soil maps at a scale of 1:10,000 to 1:25,000 as well as about 70 medium-scale soil maps at the regional level. In addition, the archive contains soil maps of different countries of the world where soil scientists carried out soil surveys in Soviet times. These maps are being digitized and updated, as necessary, using satellite data and digital soil mapping technologies.

After 1990, the joint project of the Russian Academy of Science and the International Institute for Applied Systems Analysis (IIASA) named the Land Resources of Russia was the first experience after the Soviet period of creating a unified digital database of soils at the country level (IIASA and RAS 2002).

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[12] For further information see http://web.renare.gub.uy/js/visores/coneat/.

[13] See Столбовой В., Монтанерелла Л., Медведев В., Смеян И., Шишов Л., Унгурян В., Добровольский Г., Жамань М., Кинг Д., Рожков В., Савин И. ИНТЕГРАЦИЯ ДАННЫХ О ПОЧВАХ РОССИИ, БЕЛОРУССИИ, МОЛДАВИИ И УКРАИНЫ В ПОЧВЕННУЮ ГЕОГРАФИЧЕСКУЮ БАЗУ ДАННЫХ ЕВРОПЕЙСКОГО СОЮЗА // Почвоведение. 2001. № 7. С. 773–790 (in Russian).

The project Unified State Register of Soil Resources of Russia (ЕГРПР - EGRPR) aims to perform a complete computer inventory of soils in Russia,[14] including preparing technical documentation, determining soil-ecological zoning, and compiling a collection of representative soil profiles (Stolbovoy and Molchanov 2015). The Russian Unified State Register of Soil Resources. Version 1.0 is a collective monograph of 768 pages, accepted and approved and used as an official document by the Russian Federation Ministry of Agriculture (Stolbovoy 2014). It describes a digital database based on the soil map of Russia made in 1987. The database is available on the website.[15] The regulations of the federal registration service indicate that the assessment of lands' quality for taxation should be based on the EGRPR. The Ministry of Agriculture uses the EGRPR in the framework of Russia–World Trade Organization (WTO) agreement to estimate the efficient use of Russian land for agriculture.

Work on the creation and development of the Russian Information System Soil and Geographic Database (ISSGDB) has been performed since 2008 at the initiative of the Dokuchayev Society of Soil Science;[16] this database is based on the same soil map as the one used by the EGRPR.

The ISSGDB is a network of data centers that coordinates its work and reflects the availability of primary soil information, as well as its storage locations. The system does not provide free access to data.

A data center is an organization with its own regional and subjective specialization; it collects and stores initial information in the format of international standard ISO 28258.

At present, the network of data centers includes three agrochemical centers (out of the 110 operating in Russia): the Belgorod Agrochemical Service Center (TSAS "Belgorodsky"), the Moscow Federal State Budgetary Institution State Agrochemical Service Center (FGBU GTSAS "Moskovsky"), and the Rostov Federal State Budgetary Institution State Agrochemical Service Center (FGBU GTSAS "Rostovsky"), as well as the Southern Federal University and the Faculty of Soil Science at Lomonosov Moscow State University, which also collect data on soil. The work is performed voluntarily on the basis of an agreement for scientific cooperation. Poor infrastructure imposes limits on the project development: the information is collected on hard copy and is not digitized, the format of the data collected differs, and Internet connectivity in institutions is limited.

This ISSGDB initiative may duplicate the efforts of Russia's Ministry of Agriculture to collect and summarize soil data collected by Agrochemical Service Centers; this work is carried out by the Analytical Center of the Ministry of Agriculture. Partly the data are presented on the website of the atlas of agricultural lands, which is currently actively updated by the ministry.[17]

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[14] The Unified State Register of Soil Resources of Russia (Единый государственный реестр почвенных ресурсов России) is available at http://atlas.mcx.ru/materials/egrpr/content/intro.html.

[15] See the Unified State Register of Soil Resources of Russia (Единый государственный реестр почвенных ресурсов России) at http://atlas.mcx.ru/materials/egrpr/content/intro.html.

[16] The Informational System Soil-Geographic Database of Russian Federation is available at https://en.soil-db.ru/.

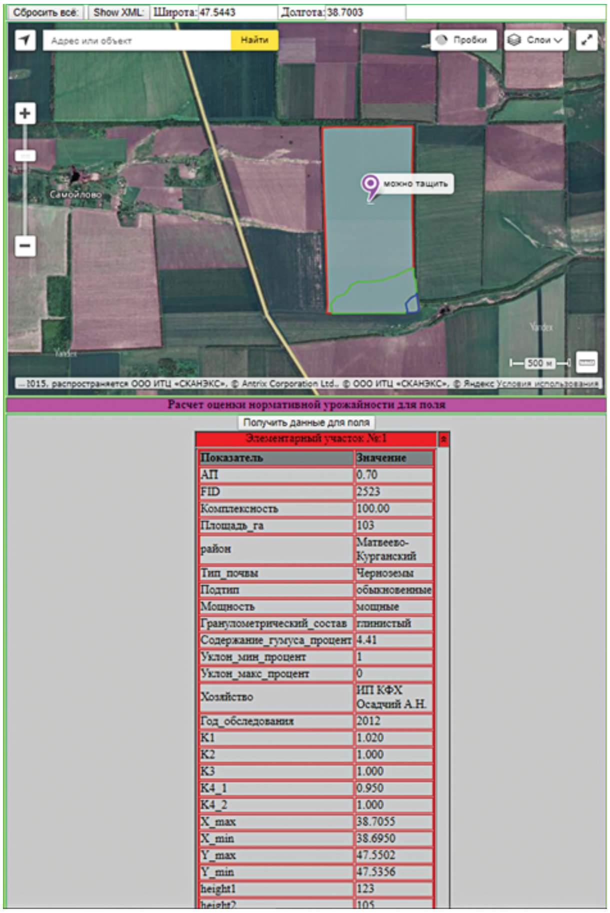
[17] Data are available at the Federal GIS Agricultural Lands Atlas http://atlas.mcx.ru/ (accessed June 6, 2018).

Derivative products can be created on the basis of the ISSGDB. One example is the subsystem for calculating the grain crop yield, functioning as part of the ISSGBD (figure 4). This is a web application for calculating the rated grain crop yield for the selected field. The calculation is based on the actual data of soil and agrochemical observations stored in the ISSGBD and correction factors; it also takes into account the area-based coefficients of agro-climatological potential capacity.[18]

In Russia, both public authorities and the private sector might be interested in creating a single soil-geographical database. The Ministry of Natural Resources and Ecology and the Ministry of Agriculture of Russia could use the data for planning the sustainable use of soil resources; creating a cadastral passport for each land plot; creating a basis for quality education and research practice; and providing a platform for the development of international relations and global projects in the spheres of food security, environmental quality, and so on (Rozhkov and others 2010).

The private sector is interested in using spatial soil data to create new products (web applications) by providing information tailored to a client's requirements. Companies engaged in precision agriculture and the production of machinery and fertilizers could be interested in using them as well.

Figure 4. Mobile application based on the EGRPR: Soil properties of the yield, calculated normative yield, and fertilizer application rates



Широта: 47.5443
Долгота: 38.7003

...2015, распространяется ООО ИТЦ «СКАНЭКС», © Antrix Corporation Ltd., © ООО ИТЦ «СКАНЭКС», © Яндекс Условия использования

Расчет оценки нормативной урожайности для поля

Элементарный участок №:1

Показатель	Значение
АП	0.70
FID	2523
Комплексность	100.00
Площадь_га	103
район	Матвеево-Курганский
Тип_почвы	Черноземы
Подтип	обыкновенные
Мощность	мощные
Гранулометрический_состав	глинистый
Содержание_гумуса_процент	4.41
Уклон_мин_процент	1
Уклон_макс_процент	0
Хозяйство	ИП КФХ Осадчий А.Н.
Год_обследования	2012
K1	1.020
K2	1.000
K3	1.000
K4_1	0.950
K4_2	1.000
X_max	38.7055
X_min	38.6950
Y_max	47.5502
Y_min	47.5356
height1	123
height2	105

Source: http://gis.soil.msu.ru/soil_db/assessment/ (in Russian only).

The interpretation of official soil data is important in order to obtain specific results for land users; the data may be interpreted by government units or agencies as well as by the private sector. For example, agronomists and horticulturists can use data to plan an erosion control program or to plan an irrigation system for farms and select suitable crops; designers, architects, and urban planners may use data to design the area. Digitized and available soil information helps to transfer technologies to different regions with similar soils, conditions, or soil limits. The experience of soil management and lessons learned may spread from one location to another. This is important especially for

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[18] Data are from the Russian Information System Soil and Geographic Database: Grain crop yield calculation, available at http://gis.soil.msu.ru/soil_db/mobile/assessment/ (accessed June 6, 2018).

small farmers and will help them to get access to new practices.

Thus the establishment of data collection infrastructure in Russia—that is, a system including policy measures, institutional arrangements, technologies, data, and qualified staff—will facilitate information exchange between regions and help achieve national and international objectives for both sustainable development and business development. This will become a significant milestone in the development of the science founded in Russia.

PART II: Digital tools stimulate agriculture market opportunities

Digital tools are important not only for helping farmers to harness the power of technical knowledge and information, but also for allowing farmers and other agricultural actors to overcome traditional barriers (isolation, asymmetric information, and so on) to become much more effective participants in both input and output markets. Two important dimensions of this phenomenon have to do with (1) dramatically improving and expanding linkages between market participants; and (2) facilitating the reliable and rapid transactions of financial assets, even in remote and cashless locations. These two functions are discussed briefly in turn in the paragraphs that follow.

Linking market participants

Digital tools are emerging that make it possible for farmers and other agricultural value chain participants quickly and efficiently to identify and contact potential partners and clients, even in remote and distant locations, whom they might otherwise never have known about. Such tools are substantially reducing transactions costs for farmers and other market participants. A popular example is farmers' use of Internet applications to find available service providers nearby with needed equipment for hire (tractors, harvesting equipment, tillage equipment, transport, and so on). This makes it possible for small farms, in particular, to take advantage of modern and capital-intensive farming techniques even if they do not have sufficient capital to purchase the needed equipment. Such tools are also making it possible for small farmers who want to sell their products, but who have only small quantities of product to sell, to find other farmers who also want to sell the same product. By selling their products together, such farmers are able to increase the scale of the sale and thus find better prices and better transport options. Digital tools are also helping farmers to find buyers for their products more easily (even if those buyers are distant) and helping them easily find shops or outlets that have key inputs in stock. Such digital applications are making markets deeper, more transparent, and more efficient—even in remote areas where isolation, thin markets, asymmetric information, and the absence of economies of scale in market transactions can be substantial obstacles to fluid market dynamics for farm-related products.

Facilitating financial transactions

Digital tools helping to facilitate financial transactions are becoming ubiquitous even in rural and remote areas where liquidity and convenient access to financial assets has been problematic in the past. Digitally facilitated transactions can be faster and more transparent and can have greater accountability than was possible in the past. Farmers can access their own resources much more quickly and reliably and in some cases get easier access to credit. The emergence of tools such as blockchain have the potential to bring greater accountability to farmers' transactions while at the same time providing the means through which to verify the origin and quality of farm produce—even for partners and consumers located thousands of miles away from the farm of origin. Such tools also enable policy instruments, such as input vouchers, that have been much more cumbersome and subject to misuse in the past. eVoucher tools and programs have become mechanisms through which to provide time-bound and limited support to targeted farmers for their purchases of farm inputs, including fertilizer and seed. By reducing transaction costs and enhancing accountability underlying transactions, such digital tools are helping to expand the business of agriculture in rural areas.

Practical examples of the use of digital technologies to stimulate agriculture market opportunities

This section considers examples of digital technologies used to find solutions that take advantage of agriculture market opportunities in Russia and around the globe.

Russian examples of digital solutions for market opportunities

Blockchain in agricultural value chains

The application of blockchain in Russian agriculture remains in the technology pilot stage for bringing in agribusiness investment and meat product traceability. The technology company TakeWing provides the blockchain backend technology for its client,[19] Agrivita, to issue an initial coin offering (ICO), an application of cryptocurrency.[20] To issue an ICO, Agrivita creates a white paper detailing the project and system seeking investment. Interested investors provide funds and in return receive the cryptocurrency in the amount stated in the white paper. The investors, however, do not gain ownership of the business. The purpose of the offering is to tap into the potential to streamline industry payment. Another example of an ICO in agriculture is issued by the Russian farmers' cooperative LavkaLavka.[21] It should be noted, however, that the use of cryptocurrency in the Russian Federation remains unregulated and, therefore, the projects do not have a legal basis.

In Tartastan, ITcoin is launched as the first cryptocurrency used for tracking beef cattle health as well as tracing the meat throughout the supply chain (Suberg 2017). Developed by Infinans,[22] ITcoin seeks to boost the local meat processing industry by increasing trust through better product and data transparency.

Blockchain, on the other hand, is known for its ability to encrypt information and publicly share such information within the network (box 2). This feature has been utilized for smart contracts, listing details of transactions, and establishing payment and delivery timeframes to improve transparency for all parties involved. In central Russia, for example, Kolionovo Farm has leveraged blockchain for smart contracts to enhance business efficiency and reliance.

To date, the technology and its application still require both public and private sectors—particularly the finance institutions, technology specialists, and business owners—to enhance regulation and provide support for the public to understand the risk and advantages of employing it.

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[19] Information about TakeWing is available at http://www.takewing.com.tw/.

[20] Information about Agrivita can be found at https://agrivita.ru/.

[21] Further information about LavkaLavka, the organic farm-to-table restaurant cooperative, can be found at http://restoran.lavkalavka.com/en/.

[22] Further information about Infinans is available at https://infinans.info/ (in Russian).

Box 2: What is blockchain?

Blockchain is a secure, shared, distributed ledger technology that decentralizes any transaction process that transfers something valuable. In a blockchain network, if a participant—also known as a node or a peer—wants a transaction, it requests the transaction, which is broadcast to all other nodes connected to the network. The transaction is validated by all other participants in the network; once this has been done, the transaction is added as a “block” to the chain of transactions that is formed to date.

Blockchain is disrupting the way trust is formed and practiced, the indispensable element behind any form of transaction involving more than one party. Going back to the conventional definition, blockchain is considered disruptive because it essentially decentralizes the authority of trust and distributes and shares the responsibility of trust to everyone in the network. Because this trust is distributed, blockchain is believed to increase transparency and enhance security because transactions are made only by consensus between involved participants and cannot be tampered with. The improved trust, in turn, enables businesses, government, and society to reduce transaction costs and lessen their dependence on intermediaries along any transaction process. To sum up, blockchain has four main characteristics. It is transparent, consensus-driven, immutable, and trustless (trust is not necessarily a requirement).a

The use of blockchain in agriculture can benefit the global food system by improving the process in which food is produced, delivered, and sold.b In particular, blockchain is believed to have immense potential in three key areas of the agriculture industry: (1) provenance and transparency; (2) mobile payments, credits, and decreased transaction fees; and (3) supply chain transactions and financing. For example, blockchain can address the issues of food quality and safety because it improves traceability and transparency within agriculture value chains. The improved traceability and the immutability of data can also help verify the accuracy of food production, certification, and food processing steps more easily and efficiently. Blockchain can also help reduce food loss and food waste costs since transactions can expedite and are less likely to be disputed in the process. Moreover, smart contracts—self-executing contracts run by a computer program that can be encoded to blockchain—enable involved parties to transact without intermediaries, eventually lowering the final price of the product for the end-consumers. The ability to skip middlemen in agricultural value chains could potentially create and improve access to finance in the developing worlds.

Challenges

Despite the opportunities that blockchain could potentially introduce, it is still too early to determine the viability and scalability of blockchain in agriculture and broader development sectors. The Center for Global Development (CGD) notes that privacy concerns for publicly shared data, operational and institutional resiliency, and governance are remaining hurdles to be addressed before applying blockchain to development challenges. Furthermore, as Agfunder points out, “connecting the technology to viable business models and compelling use cases” is the challenge for blockchain and for agri-tech at large. Last but not least, blockchain adoption in agriculture would also require a significant level of technical understanding from farmers.

Going forward

Much hype surrounds the potential of blockchain in global development, including in farming and agriculture sectors. The technology not only disrupts business as usual but also requires a fundamental change in the way society works as well as the way we think. That said, it is worth continuing the discussion on blockchain’s implications so we can harness the technology to solve the global food security challenges.

Additional resources

Noteworthy Application Cases in Agriculture

- ✓ The World Food Programme (WFP) is applying blockchain for cash transfer schemes to support Syrian refugees.
- ✓ Ripe and Filament, a blockchain project, works to make secure transfer of crop and supply chain data.
- ✓ Skuchain is leveraging its expertise in supply chain management to improve the traceability of the food supply chain by applying blockchain.
- ✓ The company Provenance helps improve the traceability of food and food origin across the supply chain.
- ✓ International Business Machines Corporation (IBM) introduced a peer-to-peer network-based weather application.
- ✓ The Dutch Ministry of Economic Affairs, the University of Wageningen, and the TNO organization introduced their proof of concept on the blockchain application for the South African table grape supply chain.

Other resources

- ✓ See Satoshi Nakamoto's original white paper on bitcoin for technical details (Nakamoto, no date)
- ✓ News articles on blockchain and agriculture featured in this note:
  - ▪ Growing the Garden: How to Use Blockchain in Agriculture (Maslova 2017)
  - ▪ From Bitcoin to Agriculture: How Can Farmers Benefit from Blockchain? (Weston and Nolet 2016)
  - ▪ Blockchain: Beyond Bitcoin to Agriculture (Gro 2018)
  - ▪ How Adoption of Blockchain Technology Will Disrupt Agriculture: Understanding the Implications of Blockchain Technology in Agriculture (Sanghera 2018)
- ✓ Blockchain and Economic Development: Hype vs. Reality by Center for Global Development
- ✓ Check out Stanford University's initiative to build the Master List of Blockchain Projects in International Development
- ✓ Listening to Podcasts? Try Smart Kitchen Show's Blockchain for Food at https://soundcloud.com/smart-kitchen-show/blockchain-for-food

Source: World Bank ICT for Agriculture Community of Practice.

a. World Bank Group Blockchain Lab 2.

b. Weston and Nolet 2016.

Global examples of digital solutions for market opportunities

Worldwide small and medium farms and agribusinesses have witnessed and experienced first-hand the revolution that digital technology can bring to their doorsteps, facilitating access to market and finance. In emerging markets especially, local innovation has burgeoned in solving issues stemming from the lack of market information, market information asymmetry, impediments to business development due to distance, and the challenges presented by long distances to financial institutions and connectivity to various existing platforms.

Linking farmers with suppliers of farm machinery services

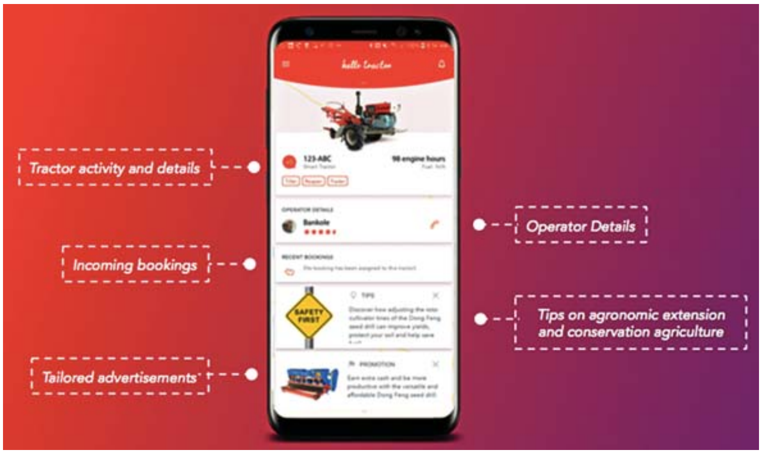
Operating in Nigeria and Kenya and entering South Asia, including Bangladesh and India, Hello Tractor brings tractor services through its mobile platform to farms upon request (figure 5). With a model similar to that of Uber, Hello Tractor leverages the notion of the sharing economy to improve farm productivity through tractor rental: instead of purchasing the machinery at a huge upfront investment, the service creates an opportunity for tractor owners to earn additional income when their fleet is idle and for renters to free up part of their financial resources by purchasing tractor services on demand.

The issues facing smallholder farmers in accessing tractors are manifold. Besides the upfront investment, the quality of existing services is not uniform or guaranteed because fleet management is poor and distant farm locations make farms difficult to reach. Trust is one other significant element dictating the success or otherwise of such rental service. Hello Tractor therefore equips compact tractors with a GPS monitoring device to keep track of the fleet's location and workload, giving insights into each tractor's status and whether it is misused or in need of maintenance. At times when the network connectivity is down, the data will be stored locally and resumed when the network comes back.

Because of the relatively isolated areas where most smallholder farms are located, the platform estimates the demand for tractor services and distance to the field to determine whether a request would trigger a task or booking to deploy the closest vehicle for work. These features help the community to maximize economic benefit from each vehicle.

Working with both private and public sectors, Hello Tractor facilitates business and revitalizes existing services that were difficult to scale. Working with the local government in Nigeria, the platform helps the agriculture agency to manage and deploy its tractor services to members of its constituency within the geographic boundary by delineating the area of coverage on the platform. With original equipment manufacturers (OEMs), the Hello Tractor products and services help OEM businesses entering frontier markets, thereby increasing supply and improving farmer access to machinery for improved productivity at a lower cost.

Figure 5. Hello Tractor owner app



Source: Hello Tractor, https://www.hellotractor.com/.

With the wealth of data gathered through the devices, Hello Tractor envisages capitalizing on the possibility of generating other farm services for small communities in the future.

For small farms, the barrier to accessing timely and appropriate financing is often a deal breaker or maker in operation planning and business investment. Situations where smallholder farmers and suppliers receive late payments or transact under long payment terms lead to unstable cash flow or insufficient working capital. Farmers and suppliers struggle to keep the business going.

Linking farmers to financing in Kenya

Leveraging digital technology, the Kenyan financial tech start-up Umati Capital provides small agribusiness players (suppliers) with up to 80 percent of the value of their receivable amount in cash, on behalf of trader, processor, or retailers (buyers).[23] This financing method, also known as factoring and invoice discounting, is seldom extended to small agribusiness players because of its higher risk and because of the difficulty in assessing small players' creditworthiness. With the ever-ubiquitous mobile devices and its in-house software solution, Umati Capital is able to monitor and access debtors such as supermarket chains transaction data through a shared API, thereby assessing credit risk via alternative methods for lending decision making (figure 6). Instead of rating small agribusinesses or farms whose data may not be available or may be time-consuming to retrieve, the evaluation of debtor creditworthiness has proven to be more efficient.

The digital solution also extends to the payment option. By partnering with Citi Bank, Umati Capital processes payments online, providing clients with quick access to funds. In 2015 Umati Capital had also partnered with Airtel Kenya to launch a bulk mobile money payment solution that had initially been developed for faster disbursals to Umati Capital clients but was later white labeled and offered to other clients by Airtel Kenya under the brand name Aida. Thanks to digital technology that enables data analytics with speed, the lending decision can be concluded within 24 hours upon receipt of relevant documents.

Linking farmers with financing in Turkey

In Turkey, a fin-tech company called Tarfin provides finance to small farms by working with input suppliers under the assumption that financing for input purchases will benefit farms the most.[24] Through an online platform, Tarfin provides point-of-sale financing to farms for the long-term goal of digitizing all segments throughout the transaction. To date, farmers are able to pick up inputs from a supplier in the vicinity once the lending decision is made; this segment of the transaction does not involve any bank notes going in or out of pockets. Nevertheless, digital banking in Turkey is not fully fledged. Paper documents such as promissory notes and physical visits to bank for repayment are required of farmers at a later stage in the process.

To further scale up and realize the digital finance objective, Tarfin stresses the importance of building a robust algorithm through alternative data to

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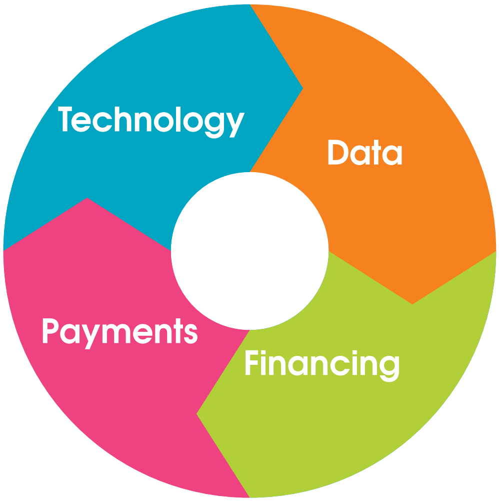
[23] Further information about Umati Capital is available at https://umaticapital.com/.

[24] Further information about Tarfin can be found at https://tarfin.com/.

Figure 6. Technology applications in the Umati Capital offering

Umati Capital

Solving the value chain problem



Technology
Web & mobile solutions capture supply chain transaction data. This reduces fraud and increases accuracy by replacing manual procurement systems

Data
Technology based transaction data provides basis for credit underwriting. This allows for alternative methods of determining creditworthiness for clients who may lack sufficient collateral

Financing
Technology enabled servicing of credit needs throughout the supply & distribution chain. Financing is delivered to the end client without paper based credit requests allowing for a 24 hour turnaround

Payments
Virtual (web & mobile) banking solutions enable our clients to gain faster access to their funds

Source: Umati Capital.

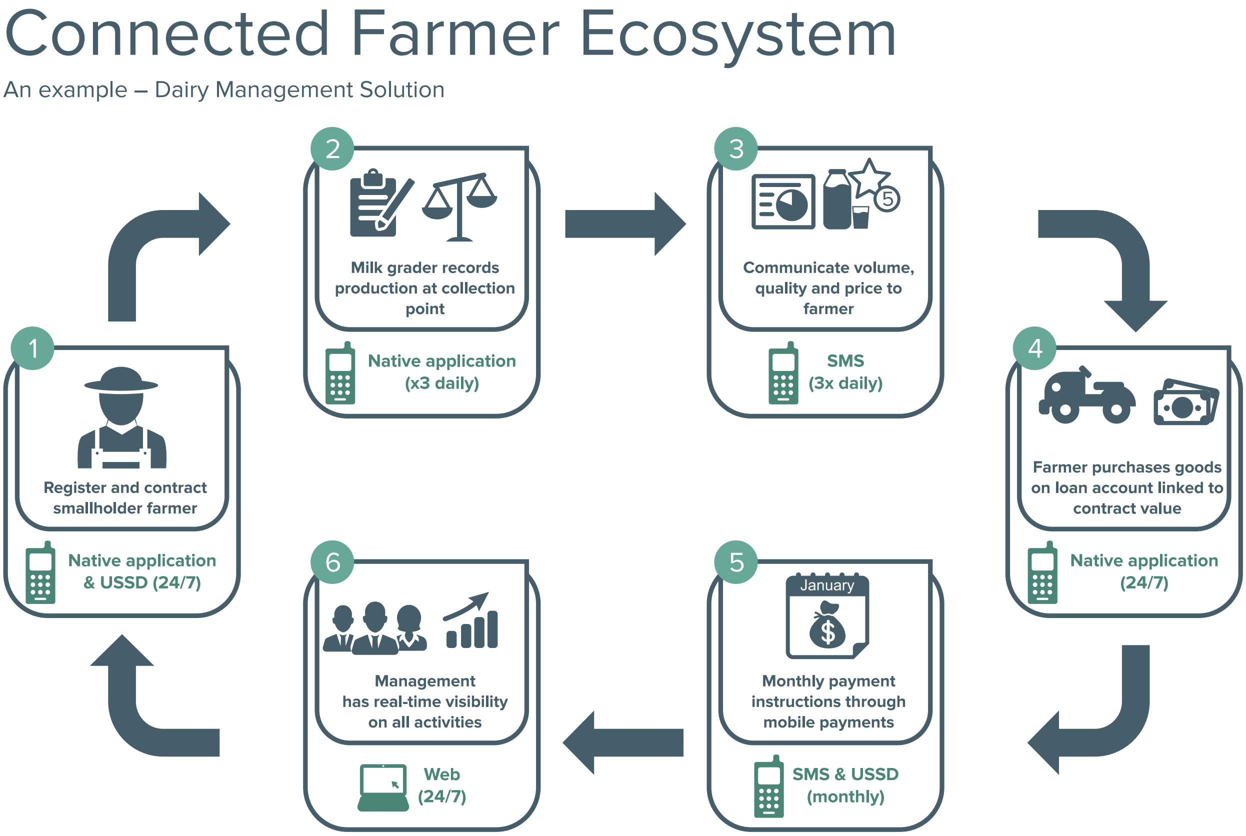
structure a credit assessment tool for farmers who do not have prior borrowing experiences. In addition, developing its input supplier network and financial institution partnership in the country will be the key to extending services to all corners of the country, and to convincing banks of the feasibility of leveraging alternative credit rating models and the bankability of small farms.

The use of smartphones to link farmers with agribusiness in East Africa

Digital technology has transformed the way farms and agribusinesses in emerging markets operate—particularly with the ever-decreasing cost of owning mobile devices. Already seemingly ubiquitous, it is anticipated that smart phones will have virtually universal coverage, and at that point even the poorest and most remote farm families will have access to diverse digital services and tools. Telecommunication companies and mobile network operators are the anchors that enable such leapfrogging to become reality. Designed specifically for the African market and supported by Vodacom's Mezzanine software, Safaricom rolled out its Connected Farmer solution, a mobile-based platform that allows agribusinesses to communicate, manage, and process payment transactions with smallholder farmers (figure 7). DigiFarm is another platform that allows smallholder farmers to receive extension services, input supplies, and financing through mobile devices.

A couple of key products on the Connected Farmer platforms include CF Seasonal, which links 150,000 macadamia farmers to Kenya Nut Company, with all transactions going through M-PESA (a leading East African mobile money option by Safaricom); Dairy Management solution, facilitating dairy cooperative member management, milk production, and delivery, tracking which data are used to rate farmer creditworthiness for input purchasing at partner

Figure 7. Connected Farmer solution for dairy management



Source: Connected Farmer.

agro-dealers. The platform also supports a closed eVoucher delivery system to ensure that the subsidies go to the target beneficiary. To date, the solutions have been piloted in seven African countries including South Africa, Nigeria, and Ghana. In Kenya 167,000 farmers have registered on Connected Farmer and 660,000 have registered on DigiFarm to receive agriculture best practice advice and input credit.

Reviewing the early success of the solutions, Vodacom resorts to the full support received from Kenya's Ministry of Agriculture in convening key stakeholders including agronomists, farm cooperatives, agro-dealers, and financial institutions to devise suitable local content and mechanisms; and from international organizations such as the African Development Bank in program design support and expert participation in communicating with member states.

Blockchain in agriculture

The advent of blockchain, one type of distributed ledger, brings the potential to revolutionize traceability and data transparency throughout the agriculture value chain. As a decentralized platform, data are encrypted and broadcast within the peer-to-peer network, enabling all parties to agree on the data authenticity before adding the new block of data onto its existing structure. The append-only characteristic prohibits deletion of the earlier information, providing data security and integrity.

To date, the majority of the blockchain applications in agriculture are in the concept stage or early pilot phase, with the private sector as the main driver of the application (Galen and others 2018, p 12). A predominant portion of agriculture blockchain initiatives is housed in the United States, Europe, or Australia; around 30 percent of their pilots are in Sub-Saharan Africa (Galen and others 2018, p 13).

In Australia, AgriDigital recently piloted blockchain technology in facilitating the national grain supply chain transparency, provenance, and matching title transfer of the grain asset to payment (AgriDigital and CBH Group 2017, p 2).

On the blockchain system, digital title was created and the grower holds the title until receiving payment from buyer, after which the title is then transferred, with quality and quantity of the commodity recorded in the system. In between, the system also handles auto-payment through cryptocurrency in parallel with standard banking methods. The exchange of digital currency and title can be processed at the rate of four transactions per second (AgriDigital and CBH Group 2017, p 3). The platform also tracks physical inventory routes, creating identification of the authenticity of organic oats, for example, through the various data points captured along the way (AgriDigital and CBH Group 2017).

In 2017 International Business Machines Corporation (IBM) deployed and piloted a blockchain application for the food industry and agribusiness financing in the United States and Africa respectively. Working with major retail stores such as Walmart, Nestlé, and Costco, the IBM blockchain system aims to boost food product traceability to mitigate recent food safety issues including contamination. The system will have the ability to help track and identify the source of contamination within the complex food supply chain for timely action.

At first sight, blockchain technology seems to be mainly serving the big conglomerates because of the advanced technology and the infrastructure investment required. In April 2018, IBM Africa in Kenya unveiled the pilot result of its partnership with the local agriculture logistics start-up Twiga Food to extend financing for the small agribusinesses it serves. Twiga Food helps smallholder farmers deliver their product to the kiosks across the country (photo 1). With this technology, agribusinesses are able to receive microfinance loans for working capital use thanks to the transaction data stored on the mobile money platform that is the main financing and transaction channel for the majority of the Kenyan population. On the IBM side, the blockchain platform assesses business creditworthiness through machine

Photo 1. Twiga Food farmers deliver produce to kiosks with help from IBM's blockchain technology

Source: IBM.

learning and an artificial intelligence algorithm that provides lending decisions.

With the immutable characteristics of blockchain, lending process transparency has increased, with additional benefits of fraud reduction. The whole process is executed through mobile devices.

Both pilots share an emphasis on how the end-user perceives such technology, considering user friendliness, the potential benefits of such technology scaling up, and whether and to what extent it adds to overall profitability. Going forward, from proof of concept to prototype, it is essential to adjust as the technology capacity evolves to deal with the ever-increasing amount of data. Commercialization of the technology will require deep customer understanding and an identification of where the opportunities lie. Regulation and policies for blockchain technology likewise require attention to ensure compliance to existing ruling and authorities.

CASE STUDY: Interoperability and the IoT ecosystem

Powered by micro- and macro-level data, precision farming enhances farm productivity and efficiency through the granular view of farm performance to inform adequate decisions and to task orders. Through sensors, GPS, and a wide range of hardware and software, the final user-friendly advice in fact undergoes a stream of processes from data collection and data management to consolidation and analytics. As diverse as the scales and types of farms in the subcategories of agriculture, the various models and versions of machinery, equipment, and information systems adopted on a farm are difficult to align.

The key characteristics of an IoT system have to do with the ability of "things"—farm objects (as nodes in the overall system)—to communicate with one another and to work together to optimize the efficiency and effectiveness of farm operations. Interoperability is thus central to maximizing IoT potential for agriculture application.

Probing into the enterprise of building an interoperable ecosystem for agriculture, the system is based on an IoT platform where data are collected from respective devices and then uploaded onto the platform; the platform stores, transmits, and enables data discovery for applications. The technology involved can be broken down to three layers: the device layer, the network layer, and the application layer (Verdouw, Wolfert, and Tekinerdogan 2016, p 5), thereby enlisting the collaboration of both public and private entities (figure 8).

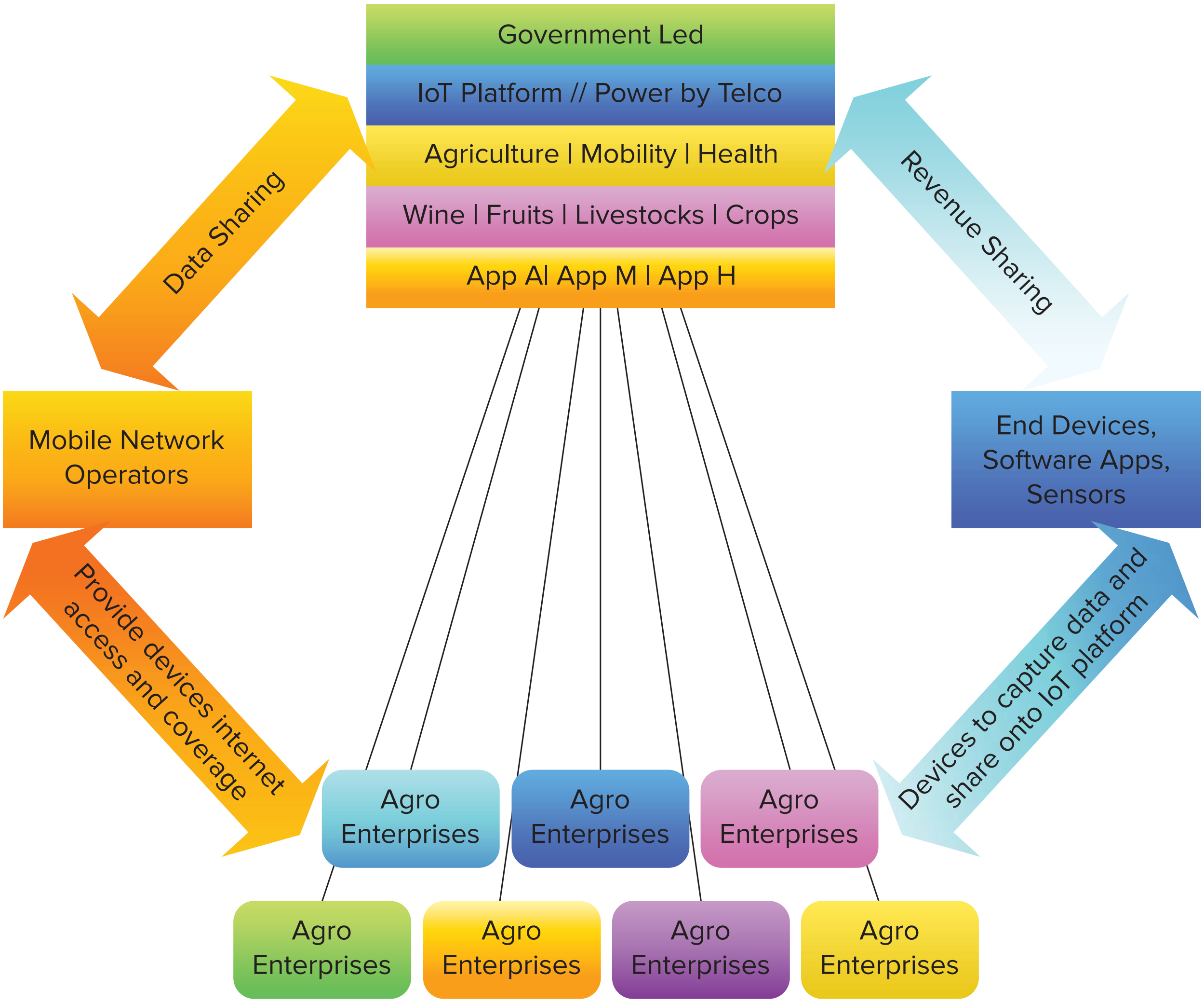
Because of the vast scale the agriculture sector encompasses, the challenges involved in scaling up IoT applications among all its stakeholders cannot be overstated. The collective insights derived from information sourced from many individual farms will prove invaluable for further product and services design within the IoT system, thereby tailoring offerings to farms of all sizes and in all subclimatic regions.

The following key policy areas have been identified to address challenges in interoperability that must be dealt with in order to unleash the full capability of digital agriculture through IoT.

- ✓ *Facilitate open data and ensure data security*

Making data available to a wide array of audiences, including software engineers, agronomists, and

Figure 8. A schematic of interoperability of an IoT system



Source: Authors

data scientists, facilitates all types of analytics to inform farm operations as well as to design products and services tailored to specific end-users' needs. Agronomic statistics housed under public authorities provide a fundamental basis for the aforementioned actors as well as mobile network operators and telecommunication companies to structure new layers onto the IoT platform, thereby deepening existing knowledge and enriching analysis for precision farming.

On the flip side of data openness, data security and privacy in an interconnected system arouse significant concerns. Agricultural data of any level—such as household surveys, farm production records, and business intelligence records—entail sensitive and confidential insights not only into individuals but also into broader geographic security or economic interests.

Legislation around the data-sharing mechanism's guiding purpose of data access, intellectual property rights, sustainable funding for system management, and licensing could shape a more favorable environment that encourages a secured and cooperative practice.

✓ *Standardize data semantics and syntax*

The advent of big data via a full spectrum of channels and devices prompts the standardization of semantics, data language, syntax, and data format, a priority to ensure interoperability. Efforts toward such standardization have been limited so far. In the agriculture sphere, the Food and Agriculture Organization of the United Nations (FAO) has established AGROVOC, a multilingual agricultural thesaurus that supports content management in agricultural information system.[25] The Global Open Data for Agriculture and Nutrition (GODAN) is another initiative convening the public and private sectors as well as high-level policy support to streamline and enhance database quality as well as usability.

✓ *Develop technology infrastructure to ensure sufficient bandwidth and storage*

Processing a wealth of data within a limited time span requires solid performance on the infrastructure front, where the IoT system operates. Stable broadband Internet and effective coverage are the catalysts for not only timely but also accurate data sharing and computation. Because of the ever-increasing quantity of available spatial and temporal data, sufficient storage for the historical database will need to be in place for comprehensive analytics.

✓ *Conduct market analysis on agriculture services and product demand*

With the data and analytic models at hand, the question now is what the demands are in terms of services, products, and applications from farms of diverse scales and across multiple geographic locations, crops, and climatic regions. A deep dive into the demand and supply of respective client segments will help shape business strategies, provide value position, and address the core pain points for end-users.

✓ *Support technology research and development*

Continuous research on technology development to advance computing speed and strengthen the existing IoT platform capacity by consolidating and expanding application capacity will propel the ecosystem to evolve and closely serve the industries. Investment in training for data scientists, technology specialists, and end-users and in rapid prototyping will speed up the IoT ecosystem evolution, thereby gaining deep customer insights to capture untapped development opportunities.

Table 2 summarizes the above discussion in matrix form. Although the majority of tasks in building an enabling IoT ecosystem require public and private partnerships, it is essential to consider also the political system and power dynamics within the country and to seek anchors and champions for specific policy agendas.

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[25] Further information about AGROVOC is available at http://aims.fao.org/vest-registry/vocabularies/agrovoc-multilingual-agricultural-thesaurus.

Table 2. Key policy issues for IoT interoperability and the role of the public and private sectors

IoT Interoperability: Russia	Public Sector	Private Sector	Public-Private Partnership
1. Open data & security	n.a.	n.a.	★
2. Language standardization	n.a.	n.a.	★
3. Infrastructure	★	★	★
4. Market research & analysis	★	★	★
5. Research & development	★	n.a.	★

Note: n.a. = not applicable.

Conclusions and areas for further work

This report has explored many examples and dimensions of how digital tools and approaches can transform, and are transforming, farming and agribusiness in Russia and around the world. It has also noted throughout that many digital tools have so far benefitted mostly large farms, posing the danger that small farms will be left behind. Several areas of future work would be very valuable to begin to develop ways to avoid leaving small farms behind. These include, among others, the following:

- ✓ What types of public sector interventions would be needed to unleash the power of digital in the form of activating agricultural information for smallholder farms in Russia? What types of interventions would be both justified (as public goods) and feasible?
- ✓ What types of public sector interventions would be needed to unleash the power of digital in the form of activating agriculture market opportunities for smallholder farms in Russia? What types of interventions would be both justified (as public goods) and feasible?
- ✓ What financing options could be explored to bring digital transformation to small farms?
- ✓ What types of system and operating environment developments would facilitate a vast expansion in the use of the power of digital in farming (especially for small farms) and agribusiness in Russia?

The foundation of digital transformation in agriculture is anchored in IT infrastructure that is supremely reliable and that has minimal latency and a stable network connectivity to process big data without a time lapse. A majority of digital progress may be spearheaded by the private sector; the public sector, nevertheless, is the main enabler to extend the technology nationwide. Public and private partnership is therefore ever more relevant as nations are ushered into the era of digital economy.

Focusing on broadening access to precise agricultural data and market opportunities for smallholder farmers, the public sector—apart from providing basic and critical infrastructure—can tap into its existing databases to inform agri-tech product design and enrich upcoming databases built by companies in the ecosystem. Additionally, security—as one of the top agenda items and main pillar for the digital paradigm to thrive—cannot be compromised. The public sector has the proper instruments and imperatives to regulate data dissemination, to prevent access by unauthorized entities, and to intervene when necessary. Only with a secured environment can trust be built in the newly established digital ecosystem.

To scale up digital technology utilization within the entire farming spectrum, and particularly the smallholder farming communities, four elements—customers, technology, competitors, and culture—are central to examining target segment contexts, issue severance, and solution relevance. These four elements inform strategies to enlist partnership, mobilize financial resources, and construct infrastructure where the existing environment is unsatisfactory.

The scaling strategy should prioritize assessing the local context and size of new markets: a landscape survey detailing the level of digitization throughout the value chain and end-users' attitude toward the innovations can provide a customer portrait that is helpful for fine-tuning product design. The state of existing infrastructure will shed light on the significance of, for instance, a tractor deficit, the satisfaction level toward the alternatives or the lack thereof, and whether the technology-based innovation will be powered by a solid IT base. These quantitative and qualitative indicators can inform an implementation plan.

Scaling up innovation requires a sustainable ecosystem encompassing supports from key anchors in public, private, and nonprofit sectors at all levels to communicate to end-users the benefits, policies, and available financing in facilitating opt-in. As is customary in the agriculture industry, stakeholders are prone to be risk averse: a dedicated engagement-communication plan will be crucial to pre-empt user resistance and to address authorities' misconceptions. Buy-in from the public sector is instrumental to de-risk new market entry by financing pilots and subsidizing uptakes to encourage wider innovation dissemination. IT infrastructure supported by private sector partners will ensure uninterrupted connectivity and machine interoperability to maximize the dividends of digital agriculture innovation to improve standards of living through increased productivity, income, and available workforce.

With the technology expertise and sectorwide determination in place, the question now is what constitutes optimal financing options to bring this transformation to small farms. The prospective options can come from the respective technology business models, which dictate stakeholder responsibilities involving investment, procurement, economic structure, and ultimately the source of finance growing from the services available on the platform. Financing mechanisms that explore fund-seeking diverse returns such as private equity, venture capital, grants, or blended finance mixing development fund and private monies are other promising approaches subject to specific scenarios and negotiations.

To seize the economic benefit of digital transformation in agriculture, Russia requires continuous technology research and development to build a global architecture that serves multiple industries simultaneously; to increase market maturity including user mindset, product pricing, and design; and to enhance public-private partnerships to devise a sustainable business model facilitating the expansion of digital technology use for the entire agriculture industry.

Annex: People and organizations consulted for the study

Entity	Key Contact	Title
Wageningen University and Research	Kees Lokhorst	Senior Researcher, Livestock Research
Kaluga Agribusiness Development Agency	Stefan Perevalov	Chief Executive Officer
Skolkovo Fdn	Roman Kulikov	Head of the direction “Biotechnology in agriculture and industry”
Agrotech Fund Skolkovo Venture Investments	Pavel Danilov	Managing Partner
Gamaya	Yosef Akhtman; Igor Ivanov	Chief Executive Officer; Chief Commercial Officer
R-Sept	Alexey Khakhunov	Chief Executive Officer
Agrivita farm	Andrey Kasatskiy	Chief Executive Officer
Panasonic Russia	German Gavrilov	Head of business development
Ericsson	Andrey Grishin	Senior Business Development Officer
	Sergey Biryukov	Account Manager
Trimble	Dudkin Denis Yurievich	Regional Manager for Agriculture, Russia and Belarus
AgTech Ventures	Roman Trofimov	Chief Executive Officer
Institute of the Information Society - Russia	Yuri Hohlov	Chairman of the Board
Exact Farming	Egor Zaikin	Director of Development
Smart4agro	Aleksander Tretyakov	Head of Consulting Department
HelloTractor	Jehiel Oliver	Chief Executive Officer
CPS - AgroNTI Coordinator	Viktor Kononov	General Director
Rabobank	Ruud Huirne	Director Food & Agri
Tarfin	Mehmet Memecan	Chief Executive Officer
Farmerline	Worlali Senyo	Director of Growth, Development and Research
Wageningen University and Research; IoF 2020 - EC	Sjaak Wolfert	Senior Scientist Data Science & Information Management in Agri-Food; Coordinator
AgroDronGroup	Dmitry Rubin	Founder
AgroTerra	Stanislav Shishov	Innovation Director
TakeWing	Alexander Kasatskiy; Ivan Lavrentiev	Lead Blockchain Developer
Vodafone	David Rhodes	Business Development Manager
Dokuchaev Soil Science Institute	Igor Savin	Deputy Research Director
Lomonosov Moscow State University	Oleg Golozubov	Researcher
United States Department of Agriculture (USDA)	Edwin Muñiz	Assistant State Soil Scientist, Natural Resources Conservation Service

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Unleashing the Power of Digital on Farms in Russia – and Seeking Opportunities for Small Farms

Farming is changing—for some farms. Rapidly emerging technologies that capture, manage, communicate, and use information in digital form are dramatically transforming the way that farming and agribusiness are done across the globe—especially for large commercial farms. Nowhere is this more true than in the Russian Federation, where many large agri-holding companies operate at the cutting edge of the application of digital technologies. These large industrial farms, with sizable land and livestock holdings, possess the financial resources and the management know-how to own and leverage the most advanced technology. Some have sophisticated information technology staff to develop and manage digital approaches to many aspects of farm operations.

However, many of Russia's farms—especially small and medium farms—lack the connectivity and skillsets needed to take advantage of such technologies. Many of these small farms also lack the equipment and the know-how to take advantage of the transformational digital opportunities from which they might profit. Yet the ever-expanding connectivity and availability of information and communication technology and digital tools could make it possible for transformational developments to happen on small, traditional, remote, and disadvantaged farms too.

This note provides an overview of the potential for digital agriculture in Russia. It surveys examples of the use of digital technologies on Russian farms today—a phenomenon that occurs for the most part in Russia's very large agro-enterprises. It examines efforts (often by the private sector) in other countries to help poorer and smaller farms adopt and take advantage of digital technologies. Finally, it indicates areas of further follow-on work that will be needed to identify measures that could be considered to expand the adoption of digital technologies in Russian agriculture—including to small farms and small agribusiness enterprises.