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Smart farming solutions for Africa: the next driver for agricultural transformation

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1. Background

The world faces a huge challenge of achieving sustainable food and nutrition security for a growing population with more diverse consumption patterns in the face of increasingly scarce natural resources and climate change. This challenge is most severe in developing countries where rates of poverty remain high. Despite recent progress, FAO estimates that more than 800 million people worldwide are hungry –consuming less than the minimum number of calories needed to sustain an active and healthy life and an estimated 160 million children are stunted, seriously impairing their future quality of life and contribution to society.

The global population is on track to surpass 9 billion by 2050 and exceed 11 billion by the end of the century. The world's 500 million smallholder farms produce around 80% of our food and it is they who will have to carry the burden of increasing food production by over 70%. Many of these smallholder farms have limited access to inputs, including mechanization, and therefore suffer from low levels of productivity and drudgery. They also have limited access to markets to take advantage of the numerous value adding opportunities. At the same time the rural population is expected to decline as, young people migrate to urban centres in search of a better life. We are also witnessing increasing feminization of smallholder agriculture, especially in Africa as more women are left in charge of the farm.

There is mounting pressure to produce more from less, as land is degraded or taken out of agricultural production, and to do so without damaging the environment on which the future of agriculture depends. In addition, increasing urbanisation imposes changes on consumption patterns, while new markets emerge, and new food safety regulations and consumers' concerns require increased quality. At the same time, the evolution of the processing industry requires the development of new products which requires new technologies and innovations.

Level of mechanization remains low in Africa where it could improve the productivity and efficiency of farms and therefore improve the lives of millions of small and medium-scale farmers.

The challenges to expand mechanization are many but the main ones in the African farming context are affordability by smallholders due to low purchasing power and remoteness to urban centres, insufficient access to credit, lack of skills needed to use agricultural machinery. Lack of suitably adapted products is often due to inadequate local manufacturing and high cost of tools, equipment, and power sources most of which is imported. Often the repair and replacement of parts are expensive or subject to a lengthy process.

The number of tractors and draught animals has been stagnating or even declining in Sub-Saharan Africa, meaning that small-farmers are relying on manual labour. Today more than 50 per cent of the cropland in Eastern and Southern Africa is cultivated by hand. Mechanisation is only applied to 20 to 25 per cent of the cropland and less than 10 per cent in West and Central Africa.

The agriculture sector employs 65% of Sub Saharan Africa's labour force and accounts for 32% of gross domestic product. The sector has gained pace over the last few years but African farm yields are amongst the lowest in the world.

In SSA, women contribute between 60 and 80% of the labour for food production and constitute the majority of smallholder farmers, provide most of the labour and manage a large part of the farming activities on a daily basis. Therefore, interventions specifically designed for women should be developed.

Benefiting from a more conducive policy environment

The Sustainable Development Goals (SDGs) have put ending poverty and hunger at the top of the global agenda. 80% of the world's extreme poor live in rural areas where most are dependent on agriculture. Therefore, raising the productivity of smallholder farmers in a sustainable way is key to achieving SDGs.

Over the last decade, Africa had some of the fastest growing economies in the world, many of them recording growing investments in agriculture and agribusiness. The Malabo Declaration commits to enhancing investment finance, both public and private, for agriculture, and promises to create appropriate policy and institutional conditions and support systems to facilitate private investment in agriculture, agri-business and agro-industries, by giving priority to local investors.

Research and innovation have led to more affordable and high-performance technologies, including precision agriculture, better-suited to the needs of small-scale farmers. The impact of climate change on the agricultural sector has led to increase awareness and urgency for action and development of climate-smart practices. Smart technologies can promote efficiencies in energy and inputs as well as reduce post-harvest losses and contribute to sound resource management of.

By investing in sustainable innovation and business models, the private sector can help transform agriculture by generating better jobs, contributing to public revenue and providing affordable goods and services.

Benefiting from a more affordable technology

The spread of mobile phone technology to billions of individuals may be the single most significant innovation that has impacted developing countries in the past decade. Across the developing world, mobile phones are used daily to transfer money, buy and sell goods, and communicate information including test results, stock levels and prices of commodities. Mobile technology is used as a substitute for poor transport infrastructures as well as underdeveloped financial and banking systems. The number of real-time information streams and people using social media is growing rapidly globally.

The new generation of agricultural machines and tools are more climate-smart sensitive and contribute to environmentally sustainable production as it is the case with conservation agriculture. Furthermore, more advanced energy-saving technology, including solar energy, contributes to more sustainable farming.

Precision agriculture for all?

Devised for industrialised farms, precision agriculture now has the potential to increase productivity of smallholder farmers while improving input use efficiency. Its application has been mostly limited to large-scale farms in developed countries. GPS-equipped sensors on tractors, for example, enable farmers to measure and respond to soil variability across vast tracts of land, and dispense the right amounts of fertiliser and water exactly where it's needed.

For many years, this was widely seen as irrelevant to small-scale farmers in developing countries. How much variability can there be on a two-hectare plot? And how could poor farmers afford the technology? But there's a growing body of research now to support the idea that small-scale farmers can benefit from precision agriculture. One of the reasons for this is greater awareness of how much variability can exist in even the tiniest plot of land.

The technology which has driven precision agriculture in the global north is becoming more widely accessible. For example, a new handheld device known as the GreenSeeker is used to measure the health and nitrogen status of plants, enabling farmers to make more precise assessments of fertiliser requirements.

European Commission promotes smart farming

In May 2014 the European Commission adopted its Communication on "A Stronger Role of the Private Sector in Achieving Inclusive and Sustainable Growth in Developing Countries". The EU is seeking ways to act as a catalyst for private financing through greater use of financial instruments such as guarantees, equity and other risk-sharing instruments for investments. "Blending" – the combination of EU grants with loans or equity from other public and private financiers, is recognised as an important means of leveraging additional resources for development and increasing the impact of EU aid. Blending will be used as a crosscutting instrument, including funds from sector allocations in fields such as energy, agriculture, water, transport and private sector development all relevant to the smart farming agenda.

The EU is allocating over 2 billion to private sector development for the period 2014 – 2020 through dedicated thematic and national EU programmes. This, together with increased allocations to regional programmes, will enhance private sector development in partner countries. An improved business climate will lay the foundation for investment and business opportunities, allowing SMEs and large enterprises to flourish in inclusive business ecosystems. Moreover, catalysing private sector investment will alleviate the huge funding gaps that exist in infrastructure sectors such as energy, water and transport.

The European Union has sponsored several projects on the topic during the Seventh Framework Programme and, now, during Horizon 2020. The currently running EU-PLF project for instance, is designed to look at the feasibility of bringing proven and cost-effective Precision Livestock Farming tools from the lab to the farm. Several private companies are also starting to be active in this field, such as Anemon (Switzerland), eCow (UK), Connected Cow (Medria Technologies and Deutsche Telekom. Smart fishing is at initial stage with some projects in Europe, South Korea, North America and Japan.

2. Realising the Promise of Agriculture for Africa's Transformation[2]

2.1 Importance of agriculture for Africa

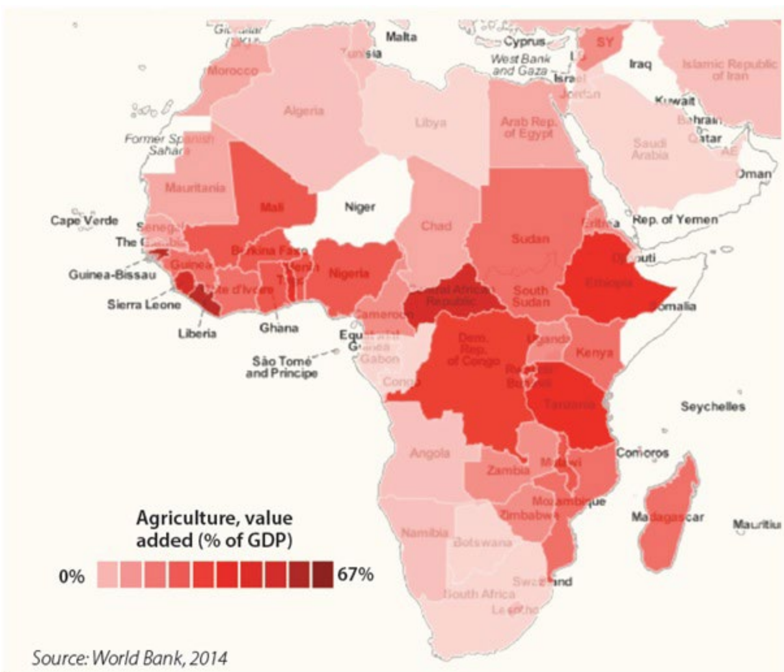
Agriculture can be a key driver of Africa's transformation because of its potential to create jobs and value-addition through increased labour and land productivity. Higher productivity, especially in yields of food staples and on smallholder farms, builds food security by increasing availability and lowering the price of staple foods. Improved access to affordable food is a critical input to structural transformation as it keeps the cost of living and labour costs low, and increases competitiveness and opportunities for manufacturing and industrial growth. Higher agricultural productivity also boosts rural incomes, helping agro-based industries and raising living standards. This increases demand for education and better skills. Rapid growth in agricultural productivity, anchored in rising yields of staple crops, could help African countries to reduce poverty and ensure rural and urban food security. Key inputs in raising agricultural productivity are better roads, railways, warehouses and communication technologies as well as access to markets.[3]

Agriculture continues to be the predominant source of employment in many regions, accounting for 63 % of rural household income in Africa, 62 % in Asia, 50 % in Europe and 56 % in Latin America. In Africa, about 65 per cent of the total labour force is employed in the agricultural sector, which contributes about 32 percent of the continent's gross domestic product (GDP).[4] Historically, agricultural growth was the precursor to industrial growth in Europe and, more recently, in parts of Asia. However, agricultural growth also has much broader linkages or multipliers and allows poor countries to diversify their economies to sectors where growth may be faster and where labour productivity and wages are typically higher. Where agricultural productivity has grown slowly, as in many parts of sub- Saharan Africa, non-farm activities have also tended to grow slowly.[5] Agricultural production in Africa has increased steadily over the last 30 years: its value has almost tripled (+160%), showing an increase that clearly exceeds the growth rate for global agricultural production over the same period (+100%), almost identical to that of South America (+174%), and below but comparable to growth in Asia (+212%).[6]

Whilst in Asia food production almost doubled and South America experienced a growth of 70%, African agriculture showed modest performances if compared with the growth of its population in the last years.[7] Notwithstanding, a great variation exists among countries. Overall, 13 African countries doubled their production in the last 20 years, among them Burkina Faso, Niger, Mali and Ghana where small scale farmers represent a great proportion of the population.[8]

Africa remains a marginal player in world trade, accounting for only 2.8 per cent of world exports (in current United States dollars) and 2.5 per cent of world imports in the decade from 2000 to 2010. The shares of both Africa and sub-Saharan Africa in world exports and imports have fallen significantly over the period from 1970 to 2011.[9]

Figure 1: Agriculture's economic importance



African agriculture still facing challenges

Agricultural production in Africa has increased only slowly over the last forty years. African agriculture is challenged by a number of threats, such as food price spikes, inadequate exploitation of land and water, rising energy and fertilizer prices and the impact of climate change on agriculture production and livelihoods. Increases in crop yields per hectare have been much slower in Africa than in any other region of the world. To some extent this may reflect low and falling soil fertility in some areas, but lack of technical innovation is commonly seen as a major factor. Africa has not experienced the same success from the Asian green revolution's innovations and dissemination of improved varieties. Less has been spent on agricultural research and development in Africa than anywhere else. Slow progress in the use of irrigation - less than 4% of crop land is irrigated - is another element hindering increases in crop yields. Addressing climate change will require important adaptation and mitigation efforts.

Non-tariff barriers, typically in the form of stringent sanitary and phytosanitary standards, can be daunting, while 'tariff escalation', by which processed farm goods attract higher import duties than unprocessed goods, discourages value addition in exporting countries.[10]

Feeding more than 9 billion people by 2050 will require doubling food production on a sustainable basis. Therefore, agriculture should be resilient - able to withstand or recover from stresses and shocks. Developing resilient agriculture will require technologies and practices that build on agro-ecological knowledge and enable smallholder farmers to counter environmental degradation and climate change in ways that maintain sustainable agricultural growth.[11] Financial markets and rural finance institutions are weak. Progress in science and technology is inadequate and agricultural research, agricultural extension, and agriculture education remain persistently underfunded.[12] Lack of a coherent policy framework and low institutional capacities for policy implementation also emerge as key factors for the poor performance of aid in African agriculture.

Successful implementation of the Comprehensive Africa Agriculture Development Policy (CAADP) can help African countries boost productivity in the agricultural sector and reverse the patterns of productivity-reducing structural change discussed above. However, this would require continued commitment to the agenda by African countries, leadership and ownership by African governments and stakeholders, and full alignment by the international development community.[13]

2.2. Agribusiness and Private Sector role in African Agricultural Transformation

Private sector interest in African agribusiness is unprecedented. The past decade has witnessed an upsurge in interest from the private sector in African agriculture and agribusiness, including interest from foreign investors and investment funds. International investors actively seek alternative venues to Asia and Latin America as a new source of supply and an opportunity for higher, risk-adjusted returns. The challenge is to harness investors' interest in ways that generate jobs, provide opportunities for smallholders, respect the rights of local communities, and protect the environment. Going forward, a key challenge is to curb speculative land investments or acquisitions that take advantage of weak institutions in African countries or disregard principles of responsible agricultural investment.[14]

In addition to international private sector interest in African agribusiness, Africa's private sector itself is also increasingly attracting investment, with much of the funding coming from domestic banks and investors and the rest from the United States and Europe. The sector is also creating an emerging African middle class of hundreds of millions of consumers. Returns to investment in Africa are among the highest in the world. Success of ICT, especially mobile phone penetration, shows how rapidly a sector can grow. It also shows how the public sector can set the conditions for the exponential growth of a vital industry that could transform the continent. Private capital flows are higher than official development assistance (and foreign direct investment is higher than in India). China, India, and others are also investing large sums in Africa. Furthermore, Africa is changing. African countries are increasingly relying on the private sector as the engine of growth and confronting governance problems, including corruption, head-on. Political support exists for the role of the state as regulator, facilitator, and agent of redistribution for equity, as shown in success stories4 such as Malian mangoes, Kenyan cut flowers or, Rwandan tourism.[15]

Private sector investment in African agriculture should be broadly understood. The principal African investors are farmers themselves. They invest around $100 billion every year in their farms, despite the almost total lack of credit facilities for the vast majority of them. However, foreign investments can be useful upstream (inputs) and downstream (processing) of agriculture to overcome the weaknesses of African industries, as well as in infrastructure to complement public funding.

Experience shows that large-scale land-based investment can be justified from an economic efficiency point of view only in a few situations, where land is truly available, which means it is not used, and is acquired in all transparency.[16]

The investment climate for agriculture includes ensuring: (i) adequate incentives for farmers from sound macro-economic, trade and sector policies; (ii) increased incentives for businesses and improvements in the business climate; (iii) reduction of transport costs for agricultural products; and (iv) reduction of barriers to inter-regional trade. It also means confirming rights to land, particularly for women, to give farmers the security to invest in their land. Farming should not be penalized by the taxation, adverse international trade conditions and negative protection for agricultural commodities that often harm African farmers.

Investments in road and irrigation infrastructures are particularly important. The unit costs of transport are reportedly far higher in Africa than in parts of Asia. High transport costs raise the cost of purchased inputs such as fertilizer and bring down farm-gate prices which reduce incentives. Also, only 7 per cent of arable land in Africa is irrigated – the figure is even lower in sub-Saharan Africa – compared with 33 per cent in Asia. Irrigation and water management promise to raise production and help farmers to deal with a more variable future climate. Given the poor record of investments in large-scale public irrigation schemes, the focus should be on small-scale schemes that can be managed by groups of farmers themselves.

Institutional and human capacity development is critical. Four types of institutions need to collaborate to support farmers in gaining access to credit, extension and markets, as well as in local and community development. These include: (i) the private sector, including businesses and farmers' and producers' associations; (ii) communities and civil society organizations; (iii) decentralized government institutions; and (iv) traditional sector institutions, which need reform to become more focused, efficient and effective. Collaboration among these institutions must be led and fostered by governments, with support from donor agencies as necessary. Governments, which have policy and financial responsibilities, need to drive decentralization and public-sector reform; opportunities to combine public and private initiatives should become apparent and ways to link small farmers with firms providing inputs, services and process or market outputs should emerge.

Greater attention must be given to making rural finance and credit markets viable in a challenging environment. This is an area where innovation is needed: new financial products need to be developed so that micro-finance can be profitable in rural areas where populations are dispersed and transaction costs high. The solution to farm investment constraints needs to come from improved agricultural incentives, better markets and increased profitability so that farmers can invest in their farms and repay loans. This can be supported by accessible low-cost savings mechanisms such as postal savings accounts.[17]

2.3. Drivers of success for Smart Faring: a combination of factors

From affordable drip watering to advanced, pricier hydroponics, smart farming has been identified as the most significant opportunity for business in the face of our global food crisis. Smart farming is identified as the number one opportunity for businesses in the 2016 Global Opportunity Report.

While farmers have always sought information such as when to plant and harvest, now advanced technology is giving both large and small-scale farmers increasingly affordable and precise tools to produce more with less.

Released by DNV GL, the United Nations Global Compact and think tank, the Global Opportunity Report analyses 15 business opportunities that stem from five major global risks. Researchers visited eight cities on five continents and asked more than 5,500 leaders in private and public sectors to rank the opportunities. Not only did smart farming top the list of solutions to the global food crisis, it came top overall, followed by possibilities in the digital labour market. Leaders in North America, sub-Saharan Africa and India demonstrate particular faith in smart farming's potential.

The report positions the humble mobile phone as the most important new agricultural tool, allowing farmers to access weather and climate data and connect to new customers. Precision farming is also important. Farmers adopting precision farming techniques can expect an 18% annual increase in income.

Other technologies range from affordable drip watering to advanced, pricier hydroponics, but all allow farmers to more precisely target water and fertiliser inputs and so can be less environmentally damaging too. Smart urban farming is identified as another chief area of opportunity, particularly vertical growing. Soil monitoring can help battle drought and drones and wireless surveillance can be deployed to more effectively manage and protect crops.

Advances in farm technology

Advances in farm technology, such as improved seed varieties, have been adopted by the majority of farmers in certain areas and for specific crops: hybrid maize in Zimbabwe in the 1980s and in Kenya since the 1960s are good examples. More recent examples include advances with cassava and rice: in one year in Uganda, mealy bug infestation led to a 90% loss in the country's cassava harvest. However, IITA has developed cassava varieties that are resistant to the mealy bug, which has triggered considerable increases in cassava production in the continent. WAREDA has also developed the NERICA rice variety, which has overcome a longstanding constraint that African rice varieties have lower yield and poorer taste than Asian varieties, but the latter are less resistant to African pests and diseases. So far NERICA looks extremely successful at increasing yields, and there are high growth rates of adoption in eastern Africa as well as western Africa.

Use of additional inputs

Although the average use of manufactured fertilizer may be low in Africa, in some areas such as highland Kenya use is similar to levels seen in Asia. Obstacles to use are less technical, more matters of logistics and the ratio of prices between the local cost of fertiliser on farm and the value of the crops grown. Recent promising developments include micro-dosing, where fertiliser is applied more precisely in time and space, thereby economising on fertiliser and gaining greater impacts on yields per unit of chemical. This makes more sense when fertiliser is relatively expensive compared to labour.

Soil and water management

Although less than 4% of the crop area is currently irrigated, the limitations may be as much economic as technical. Where there are prospects of growing high value crops in dry seasons, farmers can be quick to improve their irrigation, as seen in the Fadama valley lands in areas close to Kano where farmers have introduced diesel pumps to lift water to their plots where previously there were only shadufs in use. Some irrigation schemes that previously had disappointed in the yields achieved have been revitalised when better management has been introduced, as seen in the Office du Niger rice-growing scheme of Mali.

Investments in soil and water conservation have been undertaken, but only when it has been proved that it is profitable to do so. Good examples are the fanya juu terracing of Machakos and other parts of upland Kenya, and the planting pits and bunds deployed on the central plateau of Burkina Faso. In the fight against pests and diseases, major successes have been scored in vaccinating cattle against rinderpest, producing cassava that resists mosaic virus, and in clearing the West African savannah of the black fly that causes river blindness in humans and so deterred use of potential arable land.

Potential of uncultivated land

Africa's land potential has again been recognised. The World Bank published (2009a) an assessment of the potential of the Guinea Savannah, a vast area of some 700m ha12 that covers more than a third of the continent, and of which less than 7% is currently under crops. Until now the Guinea Savannah has been largely ignored, partly since the productive potential is medium rather than high, but largely since much of it was relatively inaccessible for lack of road access and there was little effective demand for what it could produce.

Areas geographically similar in Northeast Thailand and the Cerrado of Brazil have been transformed into major agricultural exporters: with investment and the right policies, argues the Bank, the experience could be repeated in Africa. Given future increased demand within Africa, the potential to displace currently imported food, plus possible future markets in biofuel feedstock and supplying the rapid increase in demand in Asia for vegetable oils, animal feed and other produce, large tracts of the Guinea Savannah could be tilled creating jobs, incomes and export earnings.[18]

Information and communication technologies

Increasingly, African farmers live in areas covered by telecommunications networks and can get access, albeit through loan or hire, to mobiles. Although the primary use of phones may be social, they are being used to convey market information and even to transfer money. There is clear potential for passing farmers and land managers information on physical conditions, and above all short-range weather forecasts.

Information technologies have already delivered some benefits to farmers through mobile phones in delivering economic information. There may be further applications through remote sensing with information on physical conditions passed rapidly to farmers and other land managers through cell networks.

Use of biotechnology

Although some applications are controversial, biotechnology may allow progress in solving some of the less tractable issues in crop breeding, such as improving drought resistance and encouraging nitrogen fixation. A key part of the challenge to scaling up research, development, and extension efforts will be to strengthen institutions that deliver innovations adapted to African agriculture and to build effective private-public partnerships. There is broad agreement that investment in research pays off and that they should be increased.

Making use of traditional practices encouraging sustainable agriculture

Previous development strategies to increase agricultural productivity were predominantly based on the industrial agriculture model which has often proven to be environmentally, socially and/or economically unsustainable. Sustainable agriculture shifts away from artificial methods of increasing yields towards focusing on the growing capacity of the natural inputs. This can be achieved by using a variety of techniques without affecting the environment, e.g., crop rotation, soil enrichment, and natural pest predators. Crop rotation involves growing different crops in the same field instead of planting the same crop every season. This helps to ensure the long-term health of the soil because rotating crops with nitrogen-fixing crops replace nutrients back into the soil. With the concept of sustainable agriculture, many development agencies have sought to combine the three factors of environmental, social, and economic sustainability. Agricultural sustainability aims to apply a systems approach to address different aspects of food security. It addresses above all the economic, social, and environmental dimensions of agricultural production. Thereby a systems approach is pursued, where a system consists of the interaction of different individuals and institutions—such as researchers, unions, retailers, consumers, policy makers—that need to be considered. This way different causes and impacts of agriculture and food insecurity can be identified as well as addressed.[19]

Market- and private sector-led agricultural growth

Market- and private sector-led agricultural growth refers to the idea that agricultural growth must be market-led by reducing the role of the public sector and promoting public-private partnerships.

Like the 'green revolution' in Asian countries, the new green revolution for Africa involves improving and diversifying crops, improving irrigation systems, and advancing technologies (UK Food Group 2008). This also involves strategies to achieve minimum reliance on external inputs. For example, following a sustainable agriculture perspective means addressing scope and yield stability, stable food prices, and prices of fertilizers to meet economic sustainability. Another aspect of economic sustainability is to diversify farms to avoid monoculture, thereby mitigating the risks of economic losses and responding to extreme price fluctuations associated with changes in supply and demand. Yet, this also requires a commitment to changing public policies, economic institutions, and social values.

Another important focus of sustainable agriculture is the policy level, i.e., enhance or introduce policies that promote environmental health, economic profitability, and social as well as economic equity. For example, supporting commodity and price programmes to allow farmers to realise the full benefits of the productivity gains. Another strategy is to modify tax and credit policies to encourage family farms rather than corporate concentration. It is important to address these policies at the local, regional, national, and global level, where the last is particularly important to facilitate international trade.

3. Precision agriculture: towards e-farming?

Precision agriculture (PA) or **satellite farming** or **site specific crop management** (SSCM) is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. The goal of **precision agriculture** research is to define a Decision Support System (DSS) for whole farm management with the goal of optimizing returns on inputs while preserving resources.

The practice of precision agriculture has been enabled by the advent of GPS and GNSS. The farmer's and/or researcher's ability to locate their precise position in a field allows for the creation of maps of the spatial variability of as many variables as can be measured (e.g. crop yield, terrain features/topography, organic matter content, moisture levels, nitrogen levels, pH, EC, Mg, K, etc.).

Precision agriculture has also been enabled by technologies including crop yield monitors mounted on GPS equipped combines, the development of variable rate technology (VRT) like seeders, sprayers, etc., the development of an array of real-time vehicle mountable sensors that measure everything from chlorophyll levels to plant water status, multi- and hyper-spectral aerial and satellite imagery, from which products like NDVI maps can be made.

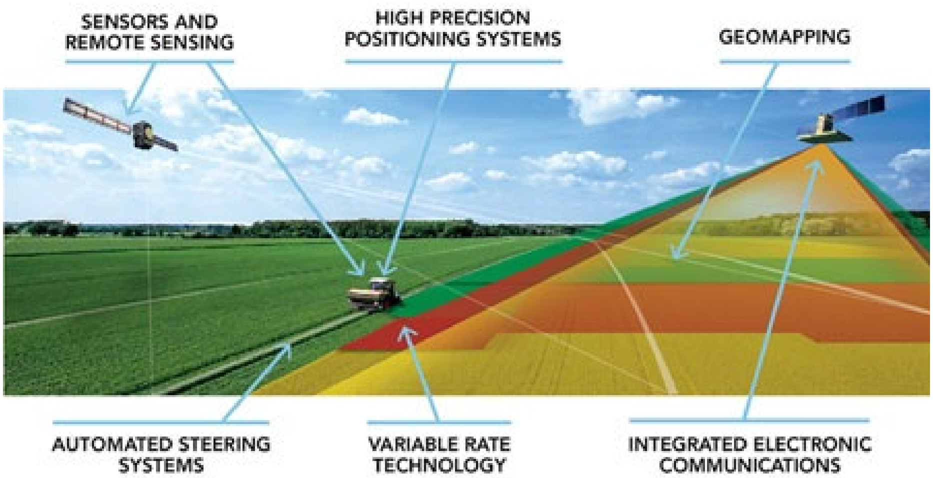
Precision agriculture is closely associated with technology and its application to large-scale farms in developed countries. Technology allows today to have GPS-equipped sensors on tractors enable to measure and respond to soil variability across vast tracts of land and dispense the right amounts of fertiliser and water exactly where it's needed.

Higher volume of data on farming activities is available than in the past. For instance, data such as farmers' credit history and the amounts of seeds and pesticides used was not available in the pre Big Data-environment. As to the data speed, near-real-time data and information on farmers' needs and capabilities are available. This means that financial institutions, produce buyers, and other relevant actors can fulfil farmers' needs more quickly than in the past. Regarding the variety, most data currently used in farming-related activities is structured data. Such data can be combined with unstructured data. For instance, farmers can upload pictures and videos related to a problem they are facing, which can be analysed by experts to offer customized advice.

3.1 Precision Farming: key technologies & concepts[20]

- **High precision positioning systems (like GPS)** are the key technology to achieve accuracy when driving in the field, providing navigation and positioning capability anywhere on earth, anytime under any all conditions. The systems record the position of the field using geographic coordinates (latitude and longitude) and locate and navigate agricultural vehicles within a field with 2cm accuracy.

- **Automated steering systems:** enable to take over specific driving tasks like auto-steering, overhead turning, following field edges and overlapping of rows. These technologies reduce human error and are the key to effective site management:



- Assisted steering systems show drivers the way to follow in the field with the help of satellite navigation systems such as GPS. This allows more accurate driving but the farmer still needs to steer the wheel.

- Automated steering systems, take full control of the steering wheel allowing the driver to take the hands off the wheel during trips down the row and the ability to keep an eye on the planter, sprayer or other equipment.

- Intelligent guidance systems provide different steering patterns (guidance patterns) depending on the shape of the field and can be used in combination with above systems.

• **Geomapping:** used to produce maps including soil type, nutrients levels etc. in layers and assign that information to the particular field location. (see picture on the left)

• **Sensors and remote sensing:** collect data from a distance to evaluating soil and crop health (moisture, nutrients, compaction, crop diseases). Data sensors can be mounted on moving machines.

• **Integrated electronic communications** between components in a system for example, between tractor and farm office, tractor and dealer or spray can and sprayer.

• **Variable rate technology (VRT):** ability to adapt parameters on a machine to apply, for instance, seed or fertiliser according to the exact variations in plant growth, or soil nutrients and type.

• **Drones in farming:** Drones have emerged as one of the most promising technologies, allowing for instance the spraying of pesticides in a more efficient and targeted way. The utilisation of drones to monitor fields investigating moisture and nutrient deficiencies in crops has massive potential for farmers while the highly advanced imaging equipment spots details too subtle for the human eye to detect.

Drone technology could help farmers around the world monitor their crops, fend off pests, improve land tenure, and more. But to realise its full potential, regulatory regimes are necessary, while keeping citizens' safety and privacy rights secure.

While UAVs are unlikely to entirely replace manned aircraft or satellites, they have a number of advantages over these more traditional remote-sensing methods. The technology is capable of collecting very high-resolution imagery below the cloud level, with much more detail than the satellite imagery usually available to developing country analysts. They are easy to use: most drone mapping and data-collection missions are now conducted autonomously, meaning that the drone essentially flies itself, while drone data processing tools are becoming less expensive and easier to use.

Perhaps most importantly, drones are inexpensive. In 2016 it is possible to purchase a useful mapping UAV for less than $1,000. And surprisingly powerful mapping drones can be built at home for even less. While processing software can be expensive, open-source and lower cost options exist. Thanks to these low barriers to entry, UAVs are expected to provide significant help to farmers in developing countries, who historically have found it harder to access aerial imagery, either from manned aircraft or from satellites.

The multiple purposes of UAVs

On the most basic level, drones permit farmers to get a big picture view of their crops, allowing them to detect subtle changes that cannot be readily identified by "crop scouts" at the ground-level. UAVs equipped with special sensors can inexpensively collect multispectral Neutral Density Vegetation Index (NDVI) and infrared (IR) images, permitting farmers to view crop changes that are otherwise invisible to the human eye. This aerial data can also be used to speed up the painstaking process of conducting crop inventories and yield estimates – such as the palm tree counts and coconut oil yield estimates in Western Samoa that are described later in this magazine.

Crop insurers and insurance policy holders also benefit from readily-available and easily repeatable drone imagery: in India, insurers plan to use UAVs to conduct assessment of crop losses after natural disasters, allowing them to more accurately and quickly calculate pay-outs, while large US crop insurers like ADM have begun running their own drone tests.

Drones also have proven useful to agricultural planners, greatly reducing the time and cost required to conduct an accurate survey. UAVs can be used to conduct volume estimates, to create irrigation and drainage models, and to collect the data needed to generate high-definition, geographically accurate elevation models and maps. In an example described in this issue, a team tasked with planning a Nigerian rice farm used drone imagery to make decisions on the layout of both rice paddies and irrigation and drainage systems – and, thanks to the drone imagery, were able to quickly determine that their original design was poorly suited to the terrain that was actually available to them.[21]

3.2 Successful applications of relevance to agriculture

Wolfgang von Loeper, a former farmer, launched in 2014 with IBM MySmartFarm app in South Africa. It leverages agriculture themed data, including climate, soil information and disease, to help farmers make the best decisions about irrigation, pest control and fertilization. Detailed information about irrigation helps farmers to irrigate only when required, and avoid wasting a precious resource.

Furthermore, developing countries are increasingly becoming the source of the technologies which are leading to the boom in big data, often through collaborative relationships and in response to the needs of sectors that have often been neglected in the technological boom. An example is the **AgriLife platform** which was developed by Kenya-based IT company MobiPay and was launched in late 2012. Mercy Corps then supported the expansion of AgriLife to Uganda and helped build relationships with other service providers and integrate them into the platform, so they can reach rural clients more effectively.[22]

Data for climate change. Through the Regional Centre for Mapping of Resources for Development (RCMRD) in Nairobi, Kenya launched a satellite tracking system that can collect real-time data from 75 percent of Africa's land area. Capable of capturing images with a 250-metre resolution, the Moderate Resolution Imaging Spectroradiometer (MODIS) monitors factors affecting the environment, like forest fires, in areas where human surveillance cannot reach without the aid of aerial photography. It enables the acquisition of direct data which can be processed into different products for a variety of applications, such as flood mapping, crop monitoring, fire assessment, water quality assessment and hailstorm prediction. The satellite receiving station in Nairobi collects data from several earth observation satellites, which it shares with the RCMRD's 15 member states in eastern and southern Africa.

Data for insurance: the automatic weather stations can show insurance companies, governments and farmers how much rain is received over a given period of time much more accurately than the weather stations. The SERVIR platform, set up in 2008, integrates satellite observation and predictive models with other geographic information to track and forecast ecological changes, and respond to natural disasters.

In Kenya, powered by solar energy, the automatic weather stations are fitted with a General Packet Radio Service (GPRS), which enables them to record rainfall data from farms within a radius of 20 km every 15 minutes (Center for Training and Research in Arid and Semi Arid Lands Development, CETRAD). Information gathered can show insurance companies, governments and farmers how much rain is received over a given period of time much more accurately than the weather stations. The SERVIR platform, set up in 2008, integrates satellite observation and predictive models with other geographic information to track and forecast ecological changes, and respond to natural disasters.

IMF and EAC team up to develop finance data

Samir Ibrahim is CEO and co-founder of Kenya-based solar irrigation company SunCulture whose AgroSolar irrigation kit promises to increase yields by up to 300% while using 80% less water than traditional farming methods. The team is now developing pay-as-you-go solar irrigation services that cost as little as $2 per day, while SunCulture-certified technicians and agronomists provide on-farm training, soil analysis and agronomy support by mobile phone. Next-day delivery and installation anywhere in Kenya is included in the price of the system, saving farmers the hassle and expense of travelling to the city to collect their irrigation system.

3.3. Implications of Big Data for Agriculture growth and value chain actors[23]

Big data can optimise the value chain and manufacturing production to more efficient use of labour. The promise of big data lies in innovation-related areas: creation of new data-intensive products; use of data to optimise or automate production or delivery processes (data-driven processes for "smart" grids, "smart" logistics and transport); use of data to improve marketing, for instance by providing targeted advertisements, data-driven marketing and design; use of data for new organisational and management approaches; use of data to enhance research and development (data-driven R&D).

Furthermore, data collected from distribution networks allow utility providers to identify losses and leakages during the distribution of energy and other resources. By deploying smart water sensors in combination with data analytics, Aguas Antofagasta, a water utility in Chile, was able to identify water leaks throughout their distribution networks and reduce total water losses from 30% to 23% over the past five years, thereby saving some 800 million litres of water a year. As in the case of public-sector data, opening smart meter data to the market has led to a new industry that provides innovative goods and services based on these data which have contributed to green growth and created a significant number of green jobs.

Big data in agriculture: the leading role of private-sector

The relationship between the private sector and big data in agriculture, particularly in developing countries, is probably consequent to the fact that the private sector has been the source of many of the key technological innovations, and subsequent diffusion of these innovations. Multinationals have played a strong role in the diffusion of new technologies which then generate big data, and the activities of enterprises, including exports, outsourcing, and licensing have led to the rapid spread of new technologies in far flung countries, including those which may not necessarily be priority countries in the development agenda. According to Kshetri, "Transnational Corporations (TNCs) such as Monsanto and Syngenta are likely to drive the international technology transfer of BD in the agricultural sector".[24]

In Africa, it is it private sector which has been most attuned to the potential of big data. According to a report by IBM, up to 40 percent of business in Kenya and Nigeria are in the planning stages of a big data project, which compares positively with the global average of 51 percent, and a further twelve percent of firms in these two countries already have big data projects, which is very close to the 13 percent global mean. The report further revealed an unforeseen impact of big data, namely that it favours small firms, as 43 percent of small firms polled said they were in the planning stage for big data projects, compared with 24 percent of medium companies.[25]

Will Big Data benefit small farmers?

Big data has small players who are especially important as generators of new applications, tools and other means of using technology in innovative ways. This is no more visible than in the area of mobile phones and other portable technology, which have spurred the demand of accessible, affordable, and resource light applications that allow users to enhance the functionality and utility of their devices, not only as means of communication or entertainment, but also as instruments in the work place, in disaster zones, in the school or laboratory.

A big challenge for big data in agriculture, particularly in developing countries, is accessibility and in some cases, affordability. Farmers, particularly smallholder farmers, are the poorest and most vulnerable stakeholders in the agricultural supply chain, and as such are at a particular disadvantage in terms being able to garner the benefits of the big data revolution.

Large growers can afford specialised machineries, which is not the case for small-farmers. The conditions that stimulated the growth of BD in the US farming industry (widespread adoption of mechanized tractors, genetically modified seeds, computers and tablets for farming activities) are less prevalent in developing countries. A main concern is that BD collection efforts will only benefit big and well-educated farmers.[26]

Big Data is needed most by farmers who least can afford it. Major corporations are investing heavily in Big Data for agriculture, and start-ups in the space are proliferating, supported by the increasing availability of venture capital. But all this market-driven activity does little to help poor, developing areas such as sub-Saharan Africa, where productivity is very low by U.S. standards and where virtually all of the world's population growth is predicted to take place in the coming decades.

As Big Data increasingly plays a role in developed countries to increase productivity, the gap between developed and developing countries can become even greater and the perceived limited application of new technologies in farming in developing countries also decreases the attractiveness of the sector for investors and for youth as a source of future employment.

Already vast amounts of information from crop yields, soil-mapping, fertiliser applications, weather data, machinery, and animal health. In a subset of smart farming, Precision Livestock Farming (PLF), sensors are used for monitoring and early detection of reproduction events and health disorders in animals.

Typical monitored data are the body temperature, the animal activity, tissues resistivity, pulse and the GPS position. SMS alerts can be sent to the breeder based on predefined events, say, if a cow is ready for reproduction.

Many farmers who have implemented data-driven prescriptive planting based on the analysis of nutrients in soil and other factors have reported a significant increase in productivity.

TNCs, which are often producers, processors, or traders of agricultural products or sellers of inputs or machinery, engage in a contracting system in which they assume a variety of responsibilities including providing technical assistance and marketing to developing world-based small farmers. TNCs such as Monsanto and Syngenta, which have become a driving force behind the utilization of BD in the industrialized world, are thus likely to act as a key channel in the international technology transfer of BD. A related point is that international technology transfer in BD is likely to have differential effects across different categories of crops. For instance, foreign companies are more active in newly emerging export crops, which are integrated into the international supply chain. Traditional cash crops such as coffee, cotton, tea, and tobacco are thus more likely to realize the need to adopt various aspects of BD (Hoeffler, 2006).

Many tractors and combines are guided by global positioning system satellites. Devised for industrialised farms, precision agriculture now has the potential to increase the yields of smallholder farmers and the technology being more widely accessible. For example, a new handheld device known as the GreenSeeker, which is based on the relationship between the light reflectance in the red and near infrared spectrum of a plant, and the nitrogen status of that plant can be used to measure the health and nitrogen status of plants, enabling farmers to make more precise assessments of fertiliser requirements. Better use of nitrogen fertiliser not only increases profitability but also reduces groundwater pollution. GreenSeeker is used in Mexico and being evaluated in Ethiopia and South Asia (CIMMYT). The GreenSeeker costs about $500 (£297), making it relatively affordable though still expensive for many small-scale farmers.

In 2013, Monsanto acquired the weather-data-mining firm Climate Corp. Likewise, the agricultural cooperative Land O'Lakes bought satellite imaging specialist Geosys. In the same vein, in order to provide real-time climate and market information to its data service users, DuPont announced collaboration with the weather-and-market analysis firm DTN/The Progressive Farmer. In 2013, Deere agreed to send data from its tractors, combines, and other machinery to the computer servers of DuPont and Dow (Bunge, 2014).

Nutrient management is another area where BD may be relevant. In Africa, outdated knowledge is pervasive and ubiquitous in recommendations for nutrient management.

This often leads to too much fertilizer in relation to potential crop demand and on a uniform basis irrespective of the type of land (Giller et al., 2011). A model-based and data-driven approach is thus likely to reduce the costs of fertilizer and increase productivity.

A further area in which BD might have potential to facilitate agricultural and farming activities in developing countries relates to the availability of near-real-time data and information regarding farmers' needs and capabilities, which can be used by value chain partners to effectively serve the farmers.

With evidence that precision agriculture techniques can work, the challenge is creating appropriate enabling environments to encourage take-up.

Machinery rings: New opportunity for farmer's access machinery

Machinery rings are composed by a grouping of farmers and others involved in agriculture who have come together to pool their resources as a means of controlling costs and making the best use of specialised equipment and expertise. The members comprise farmers, agricultural contractors, self-employed farm workers, equipment hire companies, mechanics, and business advisers.

The Ring is a form of co-operative, usually with several hundred members. There is a central office with a manager and a small number of staff who co-ordinate activities, operate the central database of members and services on offer and promote the Ring both internally and externally. The costs of the Ring are met by levying a charge on all transactions that go through the Ring, these being controlled by the central office.

A member contacts the central office to request a service, e.g. machinery, labour or both. He is put in touch with the nearest member who can satisfy that request. Payment is made via the central office. The Ring may act as a buying and/or selling group dealing with suppliers and purchasers outside of the Ring, for the benefit of the members. In addition to member-to-member work, the Ring may contract to undertake agricultural type work for third parties, on behalf of the members; e.g. land reclamation and improvement work for local authorities and English Nature. Because of the increasing sophistication of agricultural machinery, it is normal practice to supply a trained operator with any equipment hired out.

4. The way forward

While the primary driver behind smart technology is usually to reduce costs, time and wastage, smart farming has also been proven to benefit other areas such as safety and welfare, health, nutrition and sustainability. The interest for smart farming is also growing rapidly, including: yield measurement and quota systems, plant and livestock disease monitoring, remote machine control and diagnostics, greenhouse management, virtual fencing and livestock biology monitoring. And for areas such as high value crop and precision livestock farming, smart fishing and aquaculture, smart technology is helping to increase production efficiencies and generate higher profit margins.

Much of the necessary improvement will come about through smarter farming techniques, which help to optimise the agricultural production process and ultimately yields on every individual square metre of productive land to avoid the need to plough up wildlife habitats. Precision farming techniques are now well established and continue to improve as collecting and analysing vast amounts of data becomes ever more cost-effective.

Supportive policies and regulatory environments are needed for smart farming to develop in Africa and allow the farmers and entrepreneurs to capture the benefits of the technology and connectivity.

There is a need to invest in training and capacity building of farmer's organisations and a better organisation of actors of the chain. It is critical for farmers to access technology which is accessible and affordable. spare Organised groups (such as cooperatives) can facilitate group purchases or hiring services for crop operations, processing equipment and material and improved know-how in operating and maintaining them. **Collective action** not only facilitates accessibility and affordability but allows to access some types of machinery all the year around.

Increased investments in agricultural mechanization and smart farming should be promoted through enhanced participation of banks and other lending institutions, including credit lines to farmers. Equally, farmers need to be involved in R&D.

Acronyms

AAFT	African Agricultural Technology Foundation
AfDB	African Development Bank
AFRISTAT	Observatoire Economique et Statistique d'Afrique Subsaharienne
AGROST	African Group on Statistical Training and Human Resources
ASCI	Agricultural Statistics Capacity Indicator
ASDCI	Agricultural Statistics Development Composite Indicator
ASSD	Africa Symposium on Statistical Development
AGRA	Alliance for a Green Revolution in Africa
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
AU	African Union
CAADP	Comprehensive Africa Agriculture Development Programme
CBO	Community-based Organization
CEMAC	Commission de la Communauté Economique et Monétaire de l'Afrique Centrale
CGIAR	Consultative Group on International Agricultural Research
CILSS	Comité permanent Inter-états de Lutte contre la Sécheresse dans le Sahel
CMAOC	Conference of Agriculture Ministers of West & Central Africa
COMESA	Common Market for Eastern and Southern Africa
CORAF/WECARD	West and Central African Council for Agricultural Research and Development
CSO	Civil society organizations
DAC	Development Assistance Committee
EAAPP	Eastern Africa Agricultural Productivity Program
EAFF	East African Farmers' Federation
EBA	Everything but Arms
ECA	United Nations Economic Commission for Africa
ECOWAS	Economic Community of West African States

EDF	European Development Fund
EIARD	European Initiative for Agricultural Research for Development
EPAs	Economic Partnership Agreements
EU	European Union
FAAP	Framework for African Agricultural Productivity
FAO	Food & Agriculture Organisation of the United Nations
FARA	Forum for Agricultural Research in Africa
FDI	Foreign Direct Investment
FFI	Feed the Future Initiative
FNS	Food and Nutrition Security
FTF	Feed the Future initiative
GAFSP	Global Agriculture and Food Security Program
GDP	Gross Domestic Product
GFAR	Global Forum on Agricultural Research
GMO	Genetically Modified Organism
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
ICTs	Information and Communication Technologies
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development
IFC	The International Finance Corporation
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILO	International Labour Organization
IoT	Internet of Things
LDCs	Least-developed countries
LICs	Low Income Countries
MDG	Millennium Development Goal

MICs	Middle Income Countries
MFI	Microfinance Institution
NEPAD	New Partnership for Africa's Development
ODA	Official development assistance
ODI	Open Data Institute
ODP	Open Data Portal
OECD	Organisation for Economic Co-operation & Development
PAEPARD	Platform for African European Partnership on Agricultural Research for Development
PAFO	Pan-African Farmers' Organisation
PPP	Public-private Partnership
PROPAC	Regional Platform for Small Farmer Organisations of Central Africa
PRS	Poverty reduction strategy
R&D	Research and Development
RECs	Regional Economic Communities
ROPPA	Network of Farmers' and Agricultural Producers' Organisations of West Africa
SACAU	Southern African Confederation of Agricultural Unions
SADC	Southern African Development Community
SSA	Sub-Saharan Africa
UEMOA	Union Economique et Monétaire Ouest Africaine
UMAGRI	Farmers Union of the Maghreb
UN	United Nations
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
USAID	United States Agency for International Development
WAEMU	West African Economic and Monetary Union
WB	World Bank
WFP	World Food Programme
WTO	World Trade Organization

Glossary

A-B line
A straight line between two points, A and B, chosen by a machine operator and calculated by a guidance system. The A-B line defines a series of wheelings, a fixed distance apart, across the whole field. Also called guidance line.

Accuracy
In precision farming, the precision with which a positioning system can locate a point at which data is recorded or the position of a vehicle. Different systems vary in their accuracy and their suitability for different tasks. There are three levels of accuracy in a GPS system: low (+/– 50-100 cm), medium (+/– 10 cm) and high (+/– 2 cm). See also pass-to-pass accuracy, RTK accuracy, static accuracy

Active light sensor
A light sensor that emits its own light to illuminate the crop and measure the amount of light reflected from it. Active light sensors usually only capture a relatively small number of wavelengths because it is difficult to produce a bright enough light.

Active sensor
A device that generates a signal, bounces it off an object, and measures the signal reflected from the object. See also passive sensor.

Aerial digital photography
high-resolution data capture of features on the ground by a digital camera mounted on a plane or on a balloon, mast etc. Abbr. ADP

Airborne scanner
An ultrasound, laser or other scanner mounted on an aircraft, providing continuous data on ground or crop features under a flight path.

Algorithm
A set of steps or rules for making calculations or solving problems, as used in computer programs.

Analytics
Using software-based algorithms and statistics to derive meaning from data.

Analytics platform
Software or software and hardware that provides the tools and computational power needed to build and perform many different analytical queries.

Application map
A plan showing the location and rate at which seed, fertilisers or agrochemicals will be applied across a management zone. An application map is derived manually or automatically from analysis of yield maps, weed maps, etc.

Area mapping
The production of a plan which defines an area in a field or a field boundary, or calculates the size of an area, by remote sensing technology

Automatic identification and capture (AIDC)
Any method of automatically identifying and collecting data on items, and then storing the data in a computer system. For example, a scanner might collect data about a product being shipped via an RFID chip.

Automatic machine control
Computer control of operations carried out by agricultural vehicles, based on a positioning system and often combined with information collected by remote sensing technology. Automatic control can be used to control, for example, steering, headland management, spray boom height and rate of application of seed, fertilisers or agrochemicals.

Automatic steering or auto steering
A system based on GPS signals that steers a vehicle across a field without overlapping or underlapping. Auto steering is used on tractors, combines, and forage harvesters, and on self-propelled sprayers, spreaders and mowers.

Base station
A fixed site that sends and receives telecommunications signals. See also virtual base station.

Behavioral analytics
Using data about people's behavior to understand intent and predict future actions.

Big data
This term has been defined in many ways, but along similar lines. Doug Laney, then an analyst at the META Group, first defined big data in a 2001 report called "3-D Data Management: Controlling Data Volume, Velocity and Variety." Volume refers to the sheer size of the datasets. The McKinsey report, "Big Data: The Next Frontier for Innovation, Competition, and Productivity," expands on the volume aspect by saying that, "'Big data' refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze."

Biomass map
A plan that shows the variation in the crop canopy within a field, based on the data from a biomass sensor. It can indicate differences in soil fertility and therefore crop

nutrient requirements, allowing fertiliser to be applied at different rates in different places.

Biomass sensor
A remote sensor that measures biomass by measuring the light reflected from the crop canopy. The data can be combined with GPS to make maps of canopy size, indicating differences in soil fertility.

Business Intelligence (BI) Platforms
Used for integrating and analysing data specifically for businesses. BI Platforms analyse data from multiple sources to deliver services such as business intelligence reports, dashboards and visualizations.

CANBUS
A digital wiring system that connects different control units in a vehicle such as a tractor or combine, allowing data for machine control and diagnostics to be transferred between them CAN is an abbreviation of 'Controller Area Network'.

Canopy management
The careful planning of seed rates, nitrogen rates and timing of operations to achieve an optimum crop canopy for light interception. Optimum canopy should produce optimum yields in relation to nitrogen use.

Canopy sensing
The process of collecting information on crop characteristics such as biomass and chlorophyll content from a distance, by means of satellite, aerial or tractor-mounted remote sensors. See also crop reflectance.

Cassandra
A popular choice of columnar database for use in big data applications. It is an open source database managed by The Apache Software Foundation.

Cell phone data
Cell phones generate a tremendous amount of data, and much of it is available for use with analytical applications.

Cloud
A broad term that refers to any Internet-based application or service that is hosted remotely.

Cloud computing
Cloud computing is described as a service model for computing services based on a set of computing resources that can be accessed in a flexible, elastic, on-demand way with low management effort (OECD). Cloud computing has played a significant role in the increase in data storage and processing capacity. In particular, for small and medium-sized enterprises (SMEs), but also for governments that cannot, or do not want to, make heavy upfront investments in ICTs, cloud computing enables organisations to pay for supercomputing resources via a pay-as-you-go model.

Compaction
Compressed soil structure caused by pressure on the soil by vehicles, producing poor growing conditions

Soil compaction has a significant negative effect on crop yields. Factors associated with compaction that

reduce growth potential include oxygen supply, volumetric water content and vulnerability to losing nitrogen into the atmosphere; the crop may also root poorly.

Compatibility
The ability of mapping software to work with different makes of machinery control equipment.

Controlled traffic farming
A management system that ensures that all the vehicles used in a field keep to the same permanent traffic lanes every year in order to restrict compaction of the soil to the smallest possible area. he benefits are improved soil structure on untrafficked areas, which then require less tillage and have better drainage and less erosion, with resultant yield increases. Abbr. CTF; See also random traffic farming

Correction signal
A radio signal that improves the positioning accuracy provided by the basic GPS signal to much less than one metre. Inaccuracies in the GPS signal, caused by interference in the ionosphere and other factors, are measured and correction data are broadcast, also via satellite or ground system, to the GPS receiver in the tractor or other vehicle. See also EGNOS correction service, RTK accuracy

Crop canopy
The parts of a plant, especially the leaves, that receive light from the sun and shade the ground beneath. Effective canopy management ensures that each plant has the light and space to maximise yield. See also green area index, leaf area index crop reflectance the amount of visible or invisible

Crop sensing
The process of collecting information on crop characteristics such as biomass and chlorophyll content from a distance, by means of satellite, aerial or tractor-mounted remote sensors. See also crop reflectance.

Crop variability
Differences in crop yields within a field caused by factors such as differences in soil type, soil fertility, compaction and previous cropping patterns.

Data collection
In precision farming, the gathering of information on fields and crops in

digital form by sensors, in addition to data collected manually or visually data logging the automatic recording by a computer of information gathered digitally over time.

Data value chain
Underlying concept to describe the idea that data assets can be produced by private actors or by public authorities and exchanged on efficient markets like commodities and industrial parts (or made available for reuse as public goods) throughout the lifecycle of datasets (capture, curation, storage, search, sharing, transfer, analysis and visualization). These data are then aggregated as inputs for the production of value-added goods and services which may in turn be used as inputs in the production of other goods and services.

Data warehouse
A place to store data for the purpose of reporting and analysis.

Differential Global Positioning System
A system for providing a very accurate position, by calculating the difference between the actual location of a fixed-position ground station and the satellite-located position of the station, and providing a correction signal to a mobile user, either directly from a ground station or via a satellite. This system corrects for errors introduced by interference with the GPS signal and produces a very accurate signal of well below one metre, which agricultural applications require. Abbr. dGPS, DGPS

Drift
The change in a GPS position over time, by up to as much as 1.5 metres in an hour. This variation occurs as a result of changes in the orbit of the satellites providing the positioning signal, which rise and set like the sun, as well as interference to the signal by atmospheric conditions. See also static accuracy, pass-to-pass accuracy.

EGNOS correction service
A system that increases the accuracy of GPS and GLONASS signals by correcting disturbances in the ionosphere, sending corrections via the three EGNOS satellites to GPS and GLONASS users with an EGNOS receiver. It is free at the point of use. See also European Geostationary Navigation Overlay Service.

Electrical conductivity
A measure of how easily an electrical current flows through a material such as soil. The electrical conductivity of a soil sample indicates the amount of salt, sand, clay, organic matter, and water it contains, so with GPS input it can be used to create a soil map. Measurements can be taken at two depths, referred to as shallow array and deep array measurements, and the relationship between the two can provide useful information.

Electromagnetic induction
A method of measuring the electrical conductivity of soil by passing an electromagnetic wave through the ground. Abbr. EMI

Electromagnetic radiation
Radiation in the form of electromagnetic waves such as visible and invisible light rays, gamma rays, X-rays and radio waves electromagnetic spectrum the full range of electromagnetic radiation from the shortest to the longest waves electro-optical sensor a light-sensitive electronic device that creates an electrical signal proportional to the amount of electromagnetic energy that it receives.

European Geostationary Navigation Overlay Service
A European global navigation satellite system, based on three geostationary satellites, that augments the American GPS and Russian GLONASS systems by providing a system of differential correction that allows users to determine their position to within two metres, compared with about 20 metres for GPS or GLONASS alone. Abbr. EGNOS

Frequency modulated continuous wave radar
A sensing system based on microwaves suitable for short-range applications such as control of working depth or assessment of soil for the control of seedbed quality. It has advantages over sensors based on optical or ultrasound devices in that it is unaffected by features of the agricultural environment such as dust and rain. Abbr. FMCW; See also ultrasound sensor

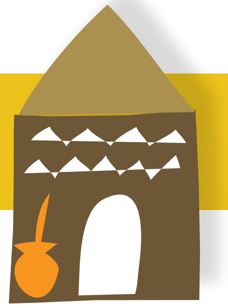
General Packet Radio Services
A system that enables phones to transfer data at high speeds, typically 32-48 kbps, and at the same time as making a voice call. Abbr. GPRS

Geographic Information System
Software that captures and processes data, associating it with a position in a field. Abbr. GIS

Georeferencing
The association of information on yield, pH, soil nitrogen or other factor with a position in a field. Map coordinates are assigned to an image derived by remote sensing.

Geostationary telecommunication satellite
A satellite in a special orbit remaining in a fixed point above the Earth's surface used for receiving and relaying radio signals.

Geostatistics
Statistics used for studying spatial patterns. Geostatistical analysis may be used to produce maps from data acquired at a relatively small set of locations.



Global navigation satellite system
Any satellite-based navigational system that can locate points on the Earth's surface. Abbr. GNSS

Global Navigation Satellite System (Globalnaya Navigatsionnaya Sputnikovaya Sistema)
A satellite-based navigational system based on a constellation of satellites owned by the Russian Federation government. Abbr. GLONASS

Global Positioning System
A satellite-based navigational system based on 24 satellites owned by the US Department of Defense GPS is often used to refer to satellite navigation systems in general. Abbr. GPS

GPS-compatible controller
A system that can operate a sprayer, spreader or drill automatically according to an application map, using the Global Positioning System.

Graphic display unit
A device that receives digital data and converts it to a visual image.

Green Area Index
the ratio of the total area of green plant tissue to the area of ground that the plant covers. t provides information on canopy size and aids decision-making on, for example, the amount and timing of nitrogen

applications. Abbr. GAI; See also leaf area index

Grid sampling
a sampling method that samples soil in squares on a grid across a field to determine soil type or fertility levels. The information can then be used to produce an application map.

Ground-based sensor
A sensor mounted on a vehicle or building.

Guidance
A system based on a positioning system that shows a driver where to steer to cover a field at the spacing required for the implement being used without overlapping or underlapping. Guided steering avoids losses from underlapping or overlapping and allows more accurate working in the dark. It is also useful where there are no tramlines to follow, as in cultivations, drilling, pre- emergence spraying, autumn fertiliser spreading and lime spreading, and on grassland.

Guided hoe
A tractor-mounted hoe that is automatically steered to correct for tractor-driving inaccuracies and allow much finer hoe tolerances. The automatic guidance system is based on a digital colour video camera that scans the crop rows ahead for green shoots.

Hackathon (also known as a **hack day, hackfest** or **codefest**)
Event in which computer programmers and others involved in software development, including graphic designers, interface designers and project managers, collaborate intensively on software projects.[1]Occasionally, there is a hardware component as well.

Hackathons typically last between a day and a week. Some hackathons are intended simply for educational or social purposes, although in many cases the goal is to create usable software.

Headland management
In precision farming, the use of a guidance system to control the turn made by a tractor at field edges automatically and precisely, controlling the implements and minimising overlap when lifting and replacing implements.The use of such a system increases the speed of turn and the accuracy of placement while reducing operator workload.

High-level accuracy
The highest level of accuracy of a positioning system to +/– 2 cm. See also RTK accuracy.

Hyperspectral reflectance spectrometry
the use of remote sensors to collect information about an object or area by building up an image based on hundreds to thousands of adjacent wavelength bands of the electromagnetic spectrum. Hyperspectral reflectance offers high resolution and may be used to help farmers assess the development, health and nutrient status of crops. See also multispectral reflectance spectrometry.

In-field variation
Differences in a factor such as yield, soil fertility or soil type in different parts of a field. Also called within-field variation.

Information management
The practice of collecting, managing, and dsitributing information of all types–digital, paper-based, structured, unstructured.

Intelligent tyres
A system that maintains tyre inflation to a preset level, automatically inflating tyres that are below target pressure using air from an air tank, or allows an operator to change tyre pressures easily according to weight, speed and soil conditions.

Internet of Services (IoS)
Refers to services which can be managed through IT and, being combined, lend themselves into value-added services. This is one to keep an eye on, especially as the service sector has become the biggest and fastest-growing business sector in the world.

Internet of Things (IoT)
Dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes and virtual personalities and use intelligent interfaces and are seamlessly integrated into the information network. More on the internet of things.

ISOBUS
An international standard, ISO 11738, for communication between tractors and implement. ISOBUS potentially allows the operation of different implements with one tractor control terminal.

L1 frequency band
A radio wave frequency band centred on 1575.42 MHz, used in transmitting satellite positioning data. See also single-frequency receiver.

L2 frequency band
A radio wave frequency band centred on 1227.60 MHz, used in transmitting satellite positioning data. It is used in conjunction with the L1 frequency band signal to correct positioning information distorted by ionosphere interference, allowing location on the ground to within several centimetres. See also dual-frequency correction.

LIDAR
an airborne system that uses height data received from laser beams scanning the ground to provide very accurate maps of the ground surface. It can be used for mapping soils, monitoring erosion, floodplain management, etc. LIDAR stands for 'Light Detection and Ranging'.

Light sensing
The process of measuring from a distance the visible and invisible light reflected from a field, soil or crop, in order to assess various characteristics and calculate their values. See also infrared sensor, light sensor

Light sensor
A device that can measure from a distance the visible and invisible light reflected from a field, soil or crop, in order to assess various characteristics and calculate their values. Infrared sensors, which monitor the light reflected from a crop that cannot be seen by the human eye, broadly measure canopy size/biomass. The total green area of a crop is calculated as the ratio of this infrared reflectance measurement to the visible green light reflected from a crop.

Location-based service
A service providing local and personalised information that can be accessed via the mobile network, based on the geographical position of a mobile phone. Services available include locating people, tracking vehicles, and weather reports. Abbr. LBS

Management zone
a part of a field, identified from the analysis of a yield map or soil map, that is defined by a specific characteristic such as soil type or fertility or weed cover and is managed in an appropriate way. A field might be divided into several management zones.

Mapping software
A computer program that uses GPS data to produce a map such as a yield map, a nutrient map or a

treatment map, or that is used for the measurement of cropping areas.

Multispectral reflectance spectrometry
the use of remote sensors to collect information about an object or area by building up an image based on tens to hundreds of adjacent wavelength bands. The image for each waveband is displayed in a different colour in a composite image. See also hyperspectral reflectance spectrometry.

Nanosensor
A highly sensitive sensor based on nanotechnology. Nanosensors are designed to perform precise functions such as measuring individual proteins or triggering electrical, chemical or enzymatic reactions in response to changing environmental conditions. See also smart sensor, remote sensor.

Non-intrusive sensor
a device that can detect information about a field, soil or crop from a distance, without requiring samples to be taken, for example, EMI measuring equipment. Also called remote sensor.

Non-trafficked soil
Soil that has not been driven over by vehicles and is therefore less compacted.

Nudge
The adjustment of guidance equipment to correct drift when a GPS position has diverged from a known position on the ground.

Open access
Practice of providing on-line access to scientific information that is free of charge to the reader.

Open Data
Free and widely available data for consultation and reuse, including reuse for commercial purposes, with a view to increasing transparency and stimulating economic activity. Applies mostly, but is not strictly limited to government data.

Open Data Center Alliance (ODCA)
A consortium of global IT organizations whose goal is to speed the migration of cloud computing.

Open source software (OSS)
Software distributed freely with its code, allowing anyone to access, to study, to redistribute and to change it. It must be distributed under a license recognised by the Open Source Initiative or the Free Software Foundation (FSF).

Operational data store (ODS)
A location to gather and store data from multiple sources so that more operations can be performed on it before sending to the data warehouse for reporting.

Parallel working
The practice of steering a vehicle across a field in parallel passes without overlapping or underlapping by using GPS guidance when carrying out operations such as cultivating, sowing, spraying or harvesting.

Passive sensor
a light sensor that captures data in daytime, by measuring the amount of light reflected from the crop (for visible wavelengths), or absorbed and then re-emitted (for thermal infrared wavelengths). Passive light sensors are affected by the angle of the sun and cloud cover, although some can correct for changes. See also active sensor.

Positioning signal
A signal broadcast by a satellite to a receiver on the ground which, when a minimum of three signals are co-ordinated, allows a location to be established.

Positioning system
A system of linked satellites that transmit radio signals to receivers on the ground, allowing a location to be accurately pinpointed. The core satellite systems are free, as are some of the enhanced dGPS systems such as WAAS (US) and EGNOS (EU). Subscription dGPS services offering high accuracy are available from commercial providers. Also called global navigation satellite system.

Precision farming
Management of farming practices that uses computers, satellite positioning systems, and remote sensing devices to provide information on which enhanced decisions can be made. Sensors can determine whether crops are growing at maximum efficiency, highly specific local environmental conditions can be identified, and the nature and location of problems pinpointed. Information collected can be used to produce maps showing variation in factors such as crop yield or soil nutrient status, and provides a basis for decisions on, for example, seed rates and application of fertilisers and agrochemicals, as well for the automatic guidance of equipment.

Precision technology
Aids such as positioning systems, remote sensors and guidance control equipment that can map variability in fields and direct inputs precisely and only where they are required.

Radiometer
A device that measures the amount of electromagnetic radiation, including visible and invisible light waves.

Radiometric data
Information on crop or soil conditions obtained by sensors detecting visible and invisible light reflected from surfaces.

Radiometric map
A plan created on the basis of the amount of visible and invisible light reflected from the area being studied. A radiometric map can identify differences such as those in soil fertility and crop disease.

Radiometry
The measurement of electromagnetic radiation, including visible and invisible light waves.

Random traffic farming
The use of tractors and other vehicles on farm land where operations are carried out in different directions without a fixed pattern of wheelings being established. Abbr. RTF

Real-time
Processing, updating and acting on data as soon as it is received from a source such as a sensor.

Real-time agronomy
The use of constantly updated data from a source such as a sensor to inform decision-making while working, for example decisions on application rates.

Real-time mapping
The production of a map by processing and updating data as soon as it is received, for example as a sprayer shows where it has sprayed.

Real-time measurement
The acquisition and processing of data while working, allowing decision- making to take place in the field, for example sensing the crop canopy, calculating an appropriate nitrogen rate and adjusting it on the move.

Real-time monitoring
The acquisition and processing of data while working, allowing decision- making to take place in the field.

Reflectance radiometry/technology
The measurement of electromagnetic radiation, including visible and invisible light waves, reflected from an object. Reflectance radiometry is used for remote sensing of soil and crop characteristics.

Reflectance sensor
A sensor that measures the amount of a type of light such as infrared light reflected from an object.

Reflectance spectrum
The part of the electromagnetic spectrum that is reflected by various materials, which reflect and absorb different wavelengths differently. Remote sensors can form images by detecting the solar radiation reflected from different objects or parts of objects on the ground.

Remote sensing
The process of detecting information about a field, soil or crop from a distance, using sensors mounted on satellites, aircraft or tractors etc.

Remote sensor
A device that collects and processes the visible and invisible light reflected from an object or area wThere are passive sensors, in which the energy that is radiated comes from an external source such as the sun, and active sensors that produce their own energy source.

Resolution
The quality of detail that can be seen in an image. The smaller the area represented by a pixel in a digital image, the more accurate and detailed the image is.

RTK accuracy
The highest level of positioning offered by a GPS system, +/– 2 cm. This system requires a base station (on a tripod or building), with a dGPS receiver and radio transmitter, to get a very local correction signal, accurate to a few centimetres. The base station can transmit to multiple vehicles up to five or six miles away depending on the terrain. Also called high-level accuracy; See also real time kinematic

RTK guidance
The use of a positioning system with an RTK correction signal to increase the accuracy of working to +/– 2 cm. See also real time kinematic, guidance.

Satellite constellation
A set of satellites orbiting the Earth and working together to give maximum coverage of its surface. Global navigation satellite systems are based on radio signals sent out by sets of linked satellites. These satellites rise and set like the sun, contributing to some of the positional errors in the signals. A means for the rapid monitoring of very large areas using a radar signal transmitted from a satellite The signal is not affected by bad weather or light conditions.

Satellite-mounted sensor
A remote sensor on a satellite that can capture large amounts of data over a large area quickly.

Scanning radiometer
A system consisting of lenses, moving mirrors, and solid-state image sensors used on satellites that produces observations of Earth and its atmosphere by converting reflected radiation into digital images.

Sensor
A device that produces an electrical signal in response to a stimulus such as light or ultrasound. See also remote sensor.

Smart sensor/nanosensor/ intelligent sensor
A sensor that can monitor its own operation and compensate for changes in operating conditions

For example, a group of smart sensors located throughout a field can be used to measure soil moisture in real time and transmit the results to a control system for irrigation.

Smoothing
A statistical technique for transforming raw data that has been collected into a map. See also kriging.

Soil hydrology
The characteristics of soil in relation to the content and movement of water.

Soil map
A plan of soil characteristics such as texture or fertility, created from a set of samples taken across an area at different depths.

Soil mapping
The production of a map of a field showing differences in soil characteristics such as texture or fertility that can be used, for example, to apply fertiliser only where it is needed and in appropriate amounts. The production of a soil map can help to reduce the high cost of fertiliser application while maintaining or even increasing yields. Also called nutrient mapping; See also grid sampling

Soil sensing
The measurement of soil characteristics by remote sensing techniques.

Soil texture map
A plan of soil type, created from a set of samples taken across an area at different depths or inferred from an EMI scan,

Soil variability
Differences in soil type and fertility across an area, as a result of previous cropping patterns, fertiliser use, underlying soil texture or compaction.

Spatial application technology
The use of data collection devices such as remote sensors to establish which areas within fields and crops need a specific treatment and then

deliver site-specific treatment to that area.

Spatial distribution
The way in which objects or features are located in an area relative to other objects or features; they may be evenly dispersed, randomly dispersed or aggregated (clumped together). Information on the spatial distribution of crop plants, weeds, diseased areas and soil types, for example, may be turned into maps on which site-specific treatments can be based. See also weed aggregation.

Spatial information
The association of measurements or observations with position in a field. Also called geographic information.

Spatial mapping
The production of a field map by associating data on factors such as soil fertility or crop health with field position.

Spatially selective treatment
The application of different rates of seed, fertiliser, or agrochemicals to soil or plants in different parts of a field, according to need. Herbicide may be applied only to patches of weeds on the basis of a weed map, or fertiliser to specific parts of a field on the basis of a nutrient map. Also called site-specific treatment.

Spectral band
A set of wavebands in the electromagnetic spectrum. See also hyperspectral reflectance spectroscopy.

Spectrometer
A device that collects and processes discrete wavelengths of radiation reflected from an object or area.

See also hyperspectral reflectance spectroscopy.

Spectroradiometer
A device that collects radiation reflected from an object or area in wavebands rather than in discrete wavelengths.

Sprayer auto-shut-off
a system that allows sections of a spray boom to be turned on and off automatically, based on the GPS position as the sprayer crosses the field. See also auto section control.

Static accuracy
The accuracy of a positioning signal over 24 hours shown on a target map resembling an archery target where the variation from a true position (the centre point) is marked. Also called long-term accuracy; See also pass- to-pass accuracy.

Submetric signal
A GPS signal that gives location accuracy of less than one metre. See also sub-metre accuracy.

Synthetic Aperture Radar
A type of radar that produces a high- resolution image of the ground by collecting the echoes of many radar signals along a flight path. It can be used to detect features such as soil moisture and crop development. Abbr. SAR

Telematics
The use of telecommunications technology to deliver and store information about the operation of tractors and combines.

Telemetry
Technology that facilitates remote monitoring and measurement.

Textural or texture image analysis
The characterisation of regions in a digital image by their texture, allowing, for example, the different leaf types of cereals and weeds to be distinguished.

Tractor-mounted sensor
A remote sensor attached to a tractor that captures data in close proximity to it with good resolution.

Traffic lane
A compacted strip of soil created by a single vehicle wheel or track.

Tramlines
Parallel lines on the ground created by the wheels or tracks of a vehicle, usually the tracks made by a sprayer or fertiliser spreader.

Treatment map
A plan that defines where the areas of a field to be treated and the application rate that should be used

A treatment map can be used to control, for example, a seed drill, a fertiliser spreader or a sprayer to deliver site-specific treatment.

Ultrasound sensor
A sensor that locates the presence or distance of an object or the ground by bouncing an ultrasound wave off it. Such sensors are often used to measure the height of a boom in automatic systems.

Uniform rate technology
The application of a single rate of seeds, fertilisers or agrochemicals across a whole field. Abbr. URT; See also variable rate technology.

Variability
The range of difference occurring in a soil, crop or other factor.

Variable rate application
The application of seeds, fertilisers or agrochemicals at different rates as required by the conditions in different parts of a field. Abbr. VRA

Variable rate technology
The devices enabling the differential application of fertilisers or agrochemicals in different parts of a field, according to an application

map or real-time sensor. Abbr. VRT; See also uniform rate technology.

Variogram
A statistical method for analysing the relationships between all possible pairs of measurements taken in different places; there is a decreasing correlation as the distance between the locations increases. It is used in advanced soil sampling. wA semi- variogram uses each data pair only once.

Vegetation index
A scale that indicates relative growth and/or vigour of green vegetation, based on a ratio and/or linear combination of measurements of reflected light in the red and near- infrared regions of the spectrum. Abbr. VI; See also normalised difference vegetative index

Virtual base station
In a GPS system, a mobile receiver that acts as a temporary base station within its zone. Abbr. VBS

Virtual reference station
In a wide-area differential GPS system, a position for which locational corrections are predicted, based on calculations from a network of base stations and the user's position. Abbr. VRS

Visible band reflectance
The reflection of light in the visible wavelengths of the spectrum from an object or area. Visible band reflectance in a crop gives an estimate of the green area index.

Visible red
Light in the red wavelengths of the spectrum which can be seen by the human eye.

Weather data
Real-time weather data is now widely available for organizations to use in a variety of ways. For example, a logistics company can monitor local weather conditions to optimize the transport of goods. A utility company can adjust energy distribution in real time.

Web 2.0
Refers to an incremental development of the technologies behind the World Wide Web, allowing the user to participate and contribute directly to the production of information, rather than being a mere passive receiver of it.

Weed mapping
The production of a plan showing where agronomically important weeds are located in a field. Many such weeds are distributed in patches, and the production of a weed map potentially allows targeted treatment with herbicides.

Weighcell
A fast, accurate electronic weighing device, used for example in fertiliser spreaders, telescopic handlers and weighbridges.

Wide Area Augmentation System
A system developed by the US government that uses a network of ground stations to measure small variations in satellite signals and produce a correction signal, giving positional accuracy of below one metre. This feature should be disabled in the UK. Abbr. WAAS

Yield mapping
The process of using GPS and yield monitoring data to show the variation in yield across a field.

Yield monitor
A device on a combine harvester that measures crop yield against field position.

Yield variation
Differences in yield across a field in any one year, or from year to year.

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Endnotes

1. Actions include: the AU Commission and NEPAD Planning and Coordinating Agency (NPCA) to develop an implementation strategy and roadmap that facilitates translation of the 2025 vision and goals of Africa Accelerated Agricultural Growth and Transformation into concrete results and impacts, and report to the January 2015 Ordinary Session of the Executive Council for its consideration; the AU Commission and RECs to facilitate the acceleration of economic integration to boost intra-Africa trade in food and agriculture.

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