Chapter 21
Future Vision, Summary and Outlook

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Abstract The DataBio's agriculture pilots were carried out through a multi-actor whole-farm management approach using information technology, satellite positioning and remote sensing data as well as Internet of Things technology. The goal was to optimize the returns on inputs while reducing environmental impacts and streamlining the CAP monitoring. Novel knowledge was delivered for a more sustainable agriculture in line with the FAO call to achieve global food security and eliminate malnutrition for the more than nine billion people by 2050. The findings from the pilots shed light on the potential of digital agriculture to solve Europe's concern of the declining workforce in the farming industry as the implemented technologies would help run farms with less workforce and manual labor. The pilot applications of big data technologies included autonomous machinery, mapping of yield, variable rate of applying agricultural inputs, input optimization, crop performance and in-season yields prediction as well as the genomic prediction and selection method allowing to cut cost and duration of cultivar development. The pilots showed their potential to transform agriculture, and the improved predictive analytics is expected to play a fundamental role in the production environment. As AI models are retrained with more data, the decision support systems become more accurate and serve the farmer better, leading to faster adoption. Adoption is further stimulated by cooperation between farmers to share investment costs and technological platforms allowing farmers to benchmark among themselves and across cropping season.

21.1 Summary of the Agriculture Pilots Outcomes

The agriculture pilots Chaps. (14–20) discuss the applications of big data technology in the agricultural arable farming, horticulture, and EU Common Agricultural Policy (CAP) support as well as in insurance assessment. The main focus of the pilot "Smart farming for sustainable agricultural production" (Chap. 15) was to offer

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smart farming advisory services for the cultivation of olives, peaches, grapes, and cotton, based on a unique combination of Earth observation (EO), big data analytics, and Internet of Things (IoT). The two-year trials' results showed a significant reduction of the number of crop protection sprays, nitrogen fertilizer applications, and irrigation water; all of which resulted in decreased production costs and increased yields. It is expected that the results achieved will be further improved as more data are produced to better train the models.

In the Genomics pilot (Chap. 16), genomic prediction and selection (GS) modeling was implemented to accurately estimate the genetic merit upon which superior cultivars can be selected, leading to simplified breeding schemes and shorter breeding cycles, all of which results in increased yields and genetic gains per unit time and cost. The GS technology showed meaningful and attractive predictive performance: the evaluated genomic selection models performed comparably across traits and were found suitable to sustain sorghum breeding for several traits including the production of antioxidants. In comparison with conventional phenotypic breeding, the genomic predictive and selection modeling allows cutting costs five times and cutting four times the time of cultivar development. These findings can lead to potential business applications such as genetic improvement of sorghum for several traits including grain antioxidants for health-promoting and specialty foods, and the use of the next-generation genotyping platforms (NGS) validated in this pilot for sequencing and genotyping services in other plant species and animal husbandry.

In Chap. 17 "Yield Prediction in Sorghum (*Sorghum bicolor (L.) Moench*) and Cultivated Potato (*Solanum tuberosum* L.)," the main objective was in-season yield prediction using satellite imageries and machine learning techniques. These pilots were established as a solution to current limitations in crop monitoring in Europe: yield forecasting approaches based mainly on field surveys, sampling, censuses, and on the use of coarser spatial (250–1000 m) resolution satellites (e.g., MODIS, SPOT-VEGETATION), all of which are unreliable and/or costly. In sorghum, it was possible to accurately predict above-ground sorghum biomass yields six months before harvesting with the best prediction times identified as days 150 and 165, i.e., late May and early June, respectively. The results from this study represent a remarkable opportunity for farmers and farming cooperatives to use this information for several business-related purposes. The models developed in this work will also help the extension services and other policymakers for strategic planning purposes, including assessing alternative means for energy supply. The potato pilot showed that smart farming services based on satellite images offer to the farmers a clear competitive advantage through better cost-effectiveness. The results from DataBio have been useful to improve the potato growth model on the basis of big data analysis. The approach contributed to better yield prediction based on the actual growing conditions with a limited number of samples or field trials. New business opportunities can be found by implementing the yield prediction model that was tested in the pilot, implementing a farmer decision support system and by further developing the potato growth model to create new services like irrigation planning and a variable rate application of fertilizers.

Chapter 18 discusses the delineation of management zones using satellite imageries based on areas with the same yield level within the fields. The method provides useful information for identifying management zones. This strategy is based on two basic principles—increasing the nitrogen (N) dosing in the zone with a higher yield (yield-oriented) or increasing the N rate in the below-average zones (homogenization). In the yield-oriented method, the N rate is determined on the basis of a nitrogen balance modeling, identifying areas with long-term lower crop yields to be fertilized with lower N rates than places with expected higher yields. In homogenization, low-yielded areas are supported by higher N doses. Homogenization is carried out when nitrogen is a yield-limiting factor and when it is appropriate to increase the booting of cereals in weak places or to homogenize the qualitative parameters of the grain.

Chapter 19 discusses farm weather insurance assessment to protect against loss or damage to crops or livestock, and to provide a value to farmers and their communities. This assessment has the potential to encourage greater agricultural investments. Copernicus satellite data series, big data technologies, and AI were used for this purpose in order to meet the most pressing needs of the insurance companies operating in agriculture: damage assessment and risk parameters estimation down to parcel level. Risk and damage assessment maps and indices were built, and this resulted in promising parametric insurance for farmer protection, and in strong reduction of ground surveys, with positive impact on insurance costs and reduction of the premium to be paid by the farmers.

Chapter 20 deals with Copernicus data and control of common agricultural policies (CAP) subsidies. The aim was to provide services to help the authorities to fulfill the requirements for the 2015–20 CAP and improve the CAP effectiveness. This should lead to a more accurate and complete farm compliance evaluation provided to paying agencies. The piloting took place in three EU countries: Greece, Italy, and Romania. Multi-temporal series of Copernicus Sentinel-2 data were deployed in this pilot to address the CAP demands for agricultural crop type identification, systematic observation, tracking, and assessment of eligibility conditions over the whole agricultural season. The results from this pilot showed that the CAP, and activities from national and regional paying agencies can benefit from the use of continuous satellite monitoring instead of random and limited controls. Stakeholders were offered the possibility to check, in a more efficient and accurate way, the compliance between the declarations made by the farmers in request of the subsidy payments and the real crop in the fields. While conventionally a minimum of 5% of the applications are cross-checked either by field sampling or by remote sensing, the methodology developed in this pilot allowed checking the compliance of the declarations submitted by the farmers for all agricultural parcels above the 0.3 ha threshold.

21.2 Evaluation of the Implemented Technologies and Future Vision

The extensive DataBio's agricultural trials were designed and conducted at the demonstration level in real production environments, i.e., in commercial fields. The outcomes from these studies were encouraging. Since several environments and business models were trialed, the conclusions and recommendations from these works are meaningful for farming business purpose on a broad scale. The agriculture pilots were run mostly as advisory services across Europe and in different areas of precision agriculture or smart farming. Whole-farm management was implemented using information technology, satellite positioning data, remote sensing and proximal data gathering, and Internet of Things technology. The overall goal was to optimize the returns on inputs while reducing environmental impacts, on the one hand, and streamlining the CAP monitoring, on the other.

Several technology adoption options were studied. The findings shed light on the potential of digital (or smart) agriculture to solve one of the major concerns in Europe, i.e., the declining workforce in the farming industry. Indeed, the high-throughput crop monitoring and risk/damage assessment, automated and intelligent agricultural input applications, in-season crop performance and yield prediction, and the (IoT) Internet connectivity solutions help to run farms with a lot less workforce and manual labor. These methods can also open up business at a global level. All in all, the main drivers of big data technologies in agriculture as implemented in the DataBio project are: (1) autonomous machinery, (2) mapping of yield and variable rate of agricultural inputs application, (3) input optimization (irrigation water, nitrogen, crop protection compounds, variable inputs application rate maps), and (4) crop performance and in-season yields prediction. Genomic prediction and selection (GS) (5) is a new and highly promising plants and husbandry breeding method which gets much attention by the main stakeholders—public and private research and development entities. The favorable GS attributes are expected to have wide-ranging implications in plant breeding as the cost and duration of cultivar development are reduced and farmers can grow a better variety faster. This helps to make more income.

21.3 Outlook on Further Work in Smart Agriculture

According to FAO, achieving global food security and eliminating malnutrition are among the most challenging issues humanity is facing. By 2050, a societal challenge will be to almost double food production from existing land areas in order to feed more than nine billion people [1, 2], while facing yield-reducing consequences of climate change and the spread of a wide range of pests and diseases [3]. Therefore, agricultural development must combine fundamental research and advanced technologies to produce more healthy food with less input. The DataBio project tackled that important challenge through a multidisciplinary approach that delivered, within three years, new knowledge to help stakeholders toward a more sustainable agriculture with reduced ecological footprint [4]. In the coming years, farmers will have to face a series of challenges such as climate change adversities (mainly drought and heat stress, and nitrogen scarcity), shrinking agricultural land areas, and depletion of finite natural resources, e.g., irrigation water. All these challenges show that the need to enhance farm yield is real and critical.

New information technologies and AI breakthroughs will impact farming in Europe and worldwide, helping reduce hunger and improve food quality. The results from the agricultural pilots confirmed the benefits gained from applying these technologies in the European farming industry. However, it is less clear in which form the technologies will be adopted and at what speed. Data is central here; as more data is gathered and AI models retrained with this data, the decision support systems become more accurate and serve the farmer better, which leads to faster adoption. It must also be noted that agriculture is less technological than other major industrial sectors [5], meaning that new technologies will meet resistance from some farmers. It is also clear that cooperation between farmers is needed to share investment costs.

The technologies implemented in the DataBio's agricultural pilots have shown their potential to transform agriculture in several aspects. Of these aspects, predictive analytics is expected to play a fundamental role in transferring big data technology into the production environment. Indeed, according to the Department for Environment Food and Rural Affairs [6], the two most common reasons for adopting precision farming techniques such as those developed in DataBio were the improved accuracy in farming operations and the reduced input costs. Likewise, crop performance monitoring and yield predictions will play a key role when they are accurately supporting the decisions of the farmer and other parties at interest. Therefore, refining the predictive analytics, especially with more historic data, will help both the farmer and the technology provider to stay on the market.

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