Assessing the Digitalization Footprint from Agricultural Fields on Required Data Storage Space

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Abstract— **The digital revolution in agriculture resulted in an accumulation of big archived data at the farmers level. Many sources of data for farmers are now available from satellite and drone images beside tractors telematics and different sensors applications. This study reports an assessment for the evolution of accumulated data from different sources at field scale. Data sources from satellite images were analysed considering the evolution of required data storage in MB/ha while drones cameras resolution and corresponding image file size were analysed from the last ten years. Moreover, archived data from a 22ha field, collected through different sensors were reported from 2005 to 2020 to assess the required data storage space. Results showed that the required data storage space from the studied 22ha field was <0.05 MB in 2005 and reached >1500 MB in 2020. Moreover, a continuous and exponential increase in the required data storage at the farmer level and a continuous increase in recent sensors generated data were reported.**

Keywords—Digital agriculture, drones, field sensors, remote sensing, digital footprint.

I. INTRODUCTION

The rapid and continuous increase in food and bioresources demand worldwide lead to an increase in the need to have more efficient and sustainable agricultural practices. Meanwhile, the current advances in electronics, telecommunication solutions and their applications in agriculture resulted in new concepts in farming management and practices which is defined as digital agriculture [1], [2]. A recent study evaluated the long term impact of digital agriculture solutions in corn field and results showed a significant increase in yield and a significant decrease in the total applied nitrogen [3]. However, the digital agriculture solutions resulted in huge archived and accumulated data from agricultural fields raising a new issue about the digitalization footprint from agricultural fields [4].

Nowadays food security and the goal of eradicating hunger are facing several challenges such as the increase of population and climate change to frequent extreme weather events [5]. This situation become worse and more challengeable with the COVID-19 pandemic as it affected the supply chain and threatening peoples access to food due to their loss of income and food increased prices [6]. The current agricultural production systems needs to cover this demand and according to the Food and Agriculture Organization of the United Nations, digital agriculture is a promising solution [7]. For instance, the availability of smart phones and related applications, personal computers and remote sensing services improved farmers and smallholders' access to information. Moreover, such digital technologies enhanced the agricultural production and productivity, reducing operational cost, improved automation, precise mechanisation, decision making and streamlining supply chains [7]. Meanwhile, the spread of theses digital technologies and related solutions will have a negative impact by reducing labour demand and will require an advanced educational programs designed for this digital agriculture era.

Currently, farmers have many data sources that support their daily and seasonally management decisions. For instance, the availability of satellite images for monitoring crops status such as drought stress and yield [8]–[10]. In the last five years, the availability of drones solutions in agriculture with its higher spatial resolution and the possibility for frequent flights through the growing season showed much potential in supporting farmers management decisions [11]. However, the accumulated data through the season and between seasons from both satellite and drone images resulted in big archived data.

Most cited impacts of digital agriculture tends to refer to precision agriculture aiming to reduce input costs and/or to increase yield while preserving the environment [12]. The current digital agriculture revolution is also often referred as agriculture 4.0 [13]. The previous revolutions in agriculture were, firstly, the shift from gathering to settled agriculture; secondly, the increase in labour and land productivity, which is commonly referred as the British revolution in the 18th century and, thirdly, the increased yield due to improved mechanization and green revolution especially in developed countries.

Data sources for farmers also extend to tractors telematics and other in-field sensors. Currently, farm tractors and machinery manufacturers support their equipment with several sensors to monitor the machine performance and support the operator for maintenance recommendations. Usually, this data is collected during the maintenance time through cable connections or through real time communication through radio communications or internet. Additionally, tractors communicate with the attached equipment, main farm office for new tasks and reporting its performance.

Furthermore, field sensors such as soil moisture content sensors, weather stations, green and weed seekers become more affordable for normal farmers [14], [15]. All these data sources accumulate and need processing which usually requires specific software to deal with its complexity. Currently, there is an increased awareness about the huge amount of produced data through the available in-field and machinery sensors. Such data has several benefits for the farmers as well as for agricultural companies who can use it for their profit optimization, performance monitoring and analysis.

The growing demand in digitalization for agricultural process associated with machinery data, communication and networking between the agricultural system components increases the risk of cyberattacks [16]. Furthermore, farmers data privacy is another issue which needs more legislations to protect farmers privacy considering the increasing number of cloud based services.

Digital agriculture solutions are increasing and getting much popular by farmers and generating more data than before. Also, these solutions will continue to improve and the demand for data storage space will subsequently increase. Therefore, this study main goal was to assess the evolution in data storage requirements for field scale considering different data sources.

II. METHODOLOGY

Currently, there are several sources of data for farmers besides data generated from agricultural fields through in-situ sensors. In order to evaluate the evolution of required data storage from different sources, this study focused on four main farm data sources as follows:

A. *Satellite images*

Satellite images are available since around 50 years back starting from Landsat-1 which launched in 1972. Early satellite images are characterized by low spatial and temporal resolution besides the limited number of spectral bands. Currently, many accurate and frequent images are available from different satellite constellations where part of them has free access to archived data. The evolution of different satellite constellations in terms of required disc space in Megabytes (MB) per hectare were calculated from Landsat (LS), QuickBird, WorldView (WV), Sentinel-2, Kompsat (KS), Pleiades (Pl), Spot (Sp) and other constellations with the corresponding satellite starting year. Only satellite constellations that provide a spatial resolution of at least one pixel/ha were considered in this analysis.

A clear understanding of such evolution can be appreciated just looking at satellite/airborne images made available by Google earth platform. Looking at such very common and widespread tool, a clear evolution can be noticed moving from 1985 to 2020: in particular the resolution and colour depth has been improving, with a noticeable advancement after 2010. In Figure 1 an example taken from a field in Texas (USA).

B. *Drone images*

In 2006, the US government approved the use of drones across the civilian airspace. Since then, many civilian applications were developed. In 2013, the first drone equipped with a camera was introduced to the commercial market model Phantom 1 developed by DJI, California, USA. The evolution of the resolution of drones RGB and multispectral cameras and the number of available bands were analysed from several developers such as: GoPro Hero (GP H), Action Cam (AC), JVC, DJI, Kodak (K), and others. The resolution information was converted to approximate image size in MB and analysed with its corresponding year of release and model.

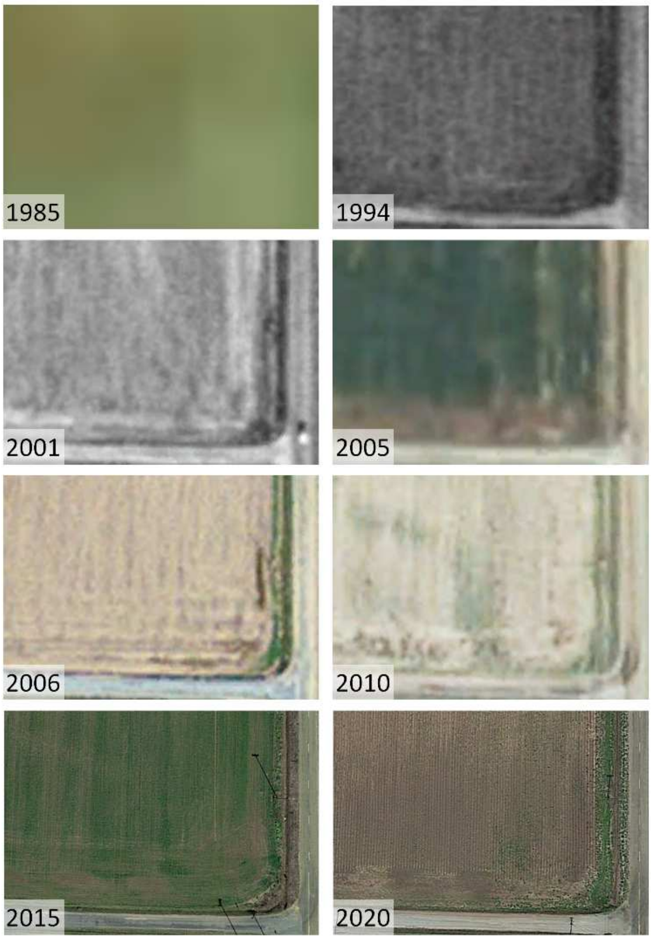

Fig. 1. Satellite images evolution example from one farm in the United States acquired from Google earth platform.

C. *Tractor telemetry*

The main purposes of farm tractors are to provide power, traction and operation for different farm equipment. Currently, new tasks are added to farm tractors in the digital agriculture and automation era. For instance, the guidance systems through GPS, fuel consumption sensors, monitoring attached equipment performance through connected sensors and cameras, different angles viewing cameras for better driver control and communicating with the main farm office for tasks control and reporting. Such reported examples require a huge flow of data between different sensors, tractor cabin, driver and the main farm office. Even if most of these data may not be valuable to be archived after each operation but even part or a summary of this data could be useful for the farm management archive. For the purpose of the present study, evaluative values were given based on the author's experience in this field.

D. Other-field data

For over 20 years, several in-field sensors with automatically archived data were commercially available for farmers. In-field sensors include weather stations, soil moisture sensors, yield monitoring systems, green and weed seekers, the developed prescription maps for nitrogen applications and planter's performance maps. Moreover, the required software to deal with such data has contributed to the farm required data storage space. In order to evaluate the evolution of in-field data storage requirements, an assessment from one case study was analysed and average values were reported in 5 years span starting from 2005 till 2020. The data were collected from a 22ha field located in Ferrara, north Italy and more details are available in [3]. Furthermore, an evaluative evolution for the required disc space from a farm weather station was reported based on the authors' experience.

III. RESULTS AND DISCUSSION

Results showed a clear increase in both satellite and drones amount of acquired data and its corresponding required disc space. Figure 2, shows the evolution of data size in MB/ha×year starting from 1972 until 2021 on a logarithmic scale. The first satellite images were from Landsat-1 where spatial resolution was 80 m with a total of four bands while currently in 2021 the Landsat-9 has 15m of spatial resolution and a total of 11 bands. Also, the highest spatial resolution was provided by WorldView-4 with 0.31 m/pixel since 2017. The required data storage space per hectare increased from <0.0001 MB/ha×year in 1972 to reach >87 MB/ha×year. This huge increase is due to the increase in spatial resolution, revisit time and number of spectral bands. Moreover, it is worth mentioning that since 2005, the number of satellite constellations increased.

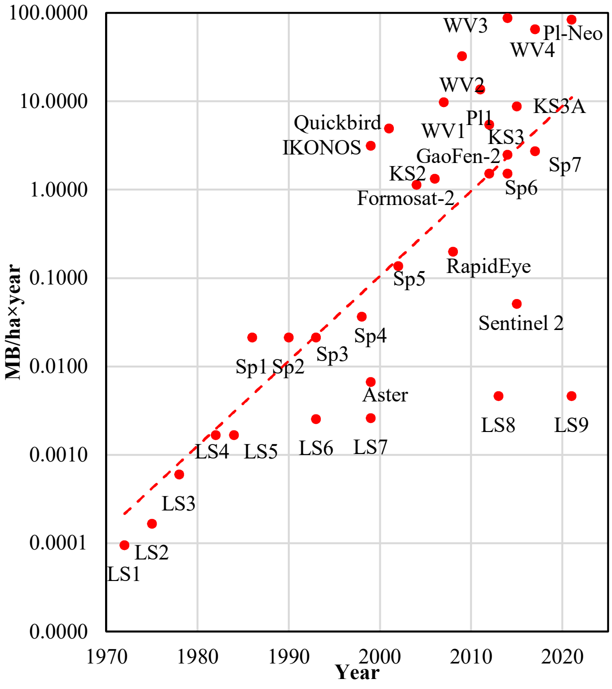

Fig. 2. Evolution of required data storage space in MB/ha.year from different satellite constellations in a logarithmic scale.

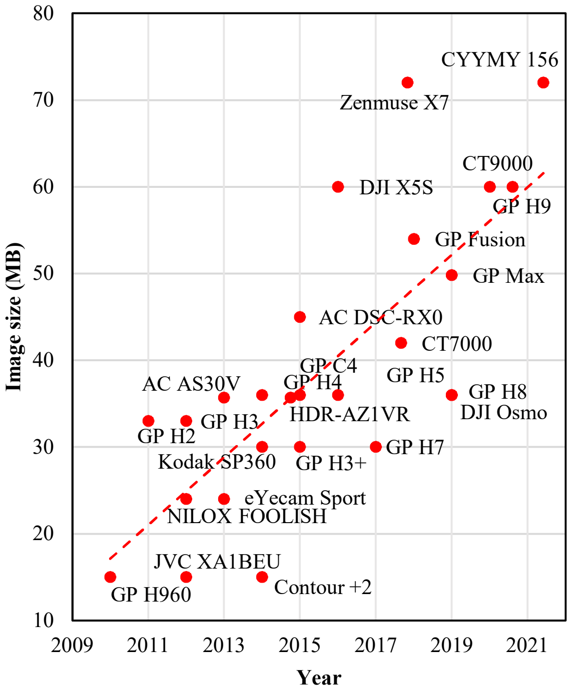

Fig. 3. Evolution in drones image size between 2010 to 2021.

Drones cameras showed a quite fast increase in required disc space per image in eleven years. Figure 3, shows the evolution in image size in MB from different cameras providers between 2010 to 2021. In 2010, the first image size was <15 MB and reached >72 MB in 2021.

Moreover, both tractor data and other field data sources showed an increase in total required disc space between 2005 and 2020. Figure 4, shows the evolution in total data storage requirements from a 22ha field. In general, in-field sensors data showed a much higher impact on the required disc space compared to tractor telemetry. Additionally, it is worth mentioning, that farmers data is accumulating from season to season leading to a continuous increase in data storage requirements.

Currently, a new commercially available weather station offers an RGB camera to capture one daily photo for the crop nearby the weather station, with an average of 1MB file size each, aimed to provide a rapid view of the field to the farmer and to create a diary of crop evolution. In Figure 5 the typical evolution of the average required disc space of annual collected weather station data is reported, based on authors experince in this field. Moreover, other sensors are commercially available with affordable prices such as planter performance, green and weed seekers and as applied fertilizers or herbicide maps [14]. Furthermore, other generated data such as prescription maps and field data analysis has also a contribution to the whole farm data storage requirements besides sensors specific software. This study results are in agreement with recent reports and publications about several digital agriculture solutions utilized by farmers and the increase in its popularity specially with young generations [3], [4].

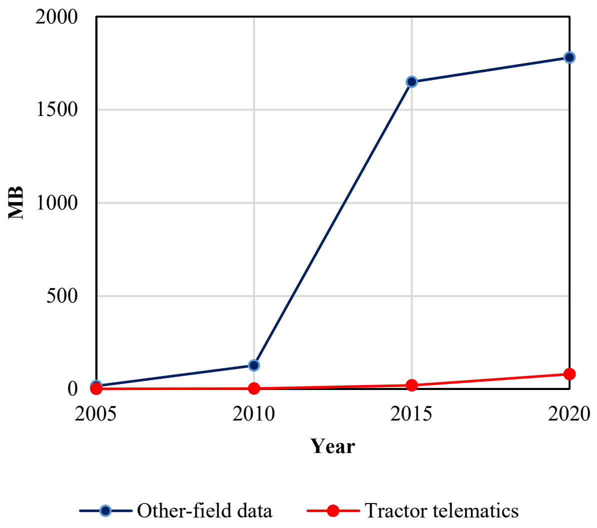

Fig. 4. Evolution of required data storage space in MB from a 22ha field for tractor telematics and other in-field sensors data.

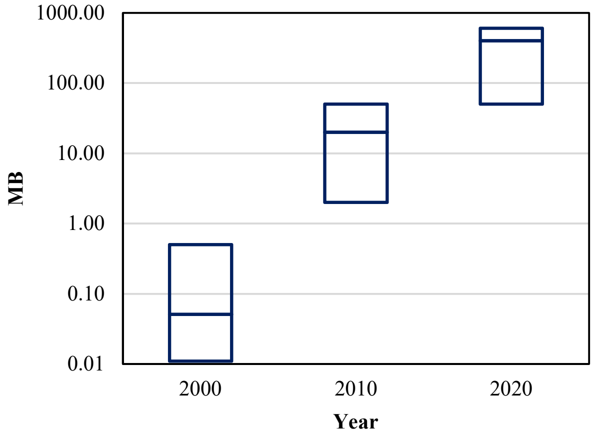

Fig. 5. An evaluative box plot on a logarithmic scale for the evolution of required data storage space in MB from a farm weather station.

While several studies reported economical and environmental benefits of different digital agriculture solutions, some limitations, constraints and cost needs to be considered. Colaco and Bramley [16], claimed that nitrogen recommendations based on sensors were often not profitable compared to common farmers nitrogen practices. For instance, the overall average reported impact from precision nitrogen application ranges between losses of 30$/ha to profits of 70$/ha [16]. A recent study by Sozzi et al, [17] analysed the cost-effectiveness of several satellite images for precision agriculture purposes and claimed that the minimum profitable area to use the free satellite images is >17ha considering the data processing costs.

Moreover, Rose et al [17], expected a change in the way of farmers management and interaction with their land due to the requirement of using the decision support tools. Such approach may lead to less dependence on farmers experience and more dependence on field data and its processing approaches. For instance, the automation for agricultural machinery practices may reduce the traffic effects on soil compaction by enhancing machinery mobility tracks through the field. Such application may improve the sugar beet quality [18]. This shift to field data based decisions may move the decision making power from farmers into private companies who collect and process their data, which rises several concerns about data privacy and probably a kind of future service monopoly and hustle.

As per this study results a 22ha field has almost 2GB of archived data without considering any drone images or archived satellite images from the same field. Considering the evolution in agricultural digital applications and previous trend in accumulated data from figure 4, it is expected to have exponential increase on collected and archived data. Here another concern with the current huge amount of collected and archived data is about the value of each layer of information. Future research in this topic may need to answer these questions: Do all of these collected data needs to be archived? In addition, what are the values of each collected layer of information? How do farmers protect their data while taking the advantage of new models and decision support tools in the current cloud computing environments?

IV. CONCLUSIONS

In conclusion, digitization footprint from agricultural fields will continue to increase as this data accumulates from year to year and more digital solutions become available and affordable for farmers with more generated and archived data. Also, the improvement in sensors in terms of spatial and temporal resolution and layers of data will lead to an exponential increase in total data storage requirements as shown in figures 2, 3, 4 and 5. Currently, some new companies are offering digital services for farmers based on cloud computing based platforms. While this solution may reduce the data storage requirements for farmers, but the environmental impact of cloud storage and data privacy issues needs to be investigated.

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