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Smart Agriculture – A systematic overview

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First, I have especially thank Prof. Barbara Pernici for all of her support
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while helping me throughout the course of the thesis.

If I would not have met her fortunately in October 2019,
I am very convinced I would have discontinued
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A devotional personality like hers, is very rare to find in a society
which seemingly becomes increasingly ignorant.
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Even if it is not always obvious, but I strongly believe,
we carry a piece of everybody in us.
Always.
Those implicit memories seem to emerge at the least expected occurrences.
Sometimes for the better, sometimes for the worse.

Life is great.

Eduard

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Abstract

Due to the latest advantages of technological progress, we are facing times of increasing data generation entering more and more into our daily life activities and businesses. The analysis of these data sets allows in principle the generic data generator, to get detailed insights of his/her observed behavioural action pattern. Rough surveys estimate that the average smartphone owner is interacting with the device on a frequency of about 150 access per day, which means as a direct data input via human-machine interaction. The workflow processes can be recorded with the help of digital technologies and the generated data can afterwards be utilized for optimization of the previously supervised processes. The following parts of this paper will present and discuss the importance of utilizing the data for analysis in the realm of agricultures. To give a more precise example how this might be translated in a technical use case, would be the integration of weather data for the irrigation of the crops. On days where rain is expected to fall on the fields, a sensor could communicate to the receiving farmer to not water his crops and therefore create savings. Several different combinations within the possibilities are thinkable, summarized with the term, Smart Agriculture.

A "one-size-fits-all-solution" approach for every existing agriculture in the world would be too holistic and non-executable, since the to-be-analysed properties are changing incrementally daily, depending on environmental and personal influences. In the following this paper describes the usage of data analysis systems for the agricultural sector in various aspects. But the fundamental idea remains by leveraging one's business performance with the help of underlying information processes, allowing data-driven support for sophisticated decision making in order to facilitate the work of the farmer.

The high variability and multiple sources of the generated data, generates data stacks in such a huge scale; therefore, the name Big Data would be more precise to be used in these cases. This is from highly relevance within the field of the agricultural sector, because of the rich information ranging from the agricultural machinery sensory input, over details of soil content, up to the wildlife behaviour of the area in usage.

Beginning with an introduction describing the necessity and importance for data analysis for agricultural systems, followed with the literature review about the state of the art, continued by suggesting a strategic approach for farmers to join the emerging data-sharing platforms. Another chapter will be dedicated for connecting the dots of the previously covered points, to give a glimpse how a fully connected agriculture in the fully digitalized world could look alike, enabling a production of demand for the served agents. The thesis is going to be finished with the concluding remarks.

Sommario

A causa degli ultimi vantaggi del progresso tecnologico, ci troviamo di fronte a periodi di crescente generazione di dati che entrano sempre più nelle nostre attività quotidiane e lavorative. L'analisi di questi insiemi di dati consente al generatore di dati di ottenere informazioni sempre più dettagliate sul modello di azione comportamentale osservato. I sondaggi approssimativi stimano che il proprietario medio di uno smartphone-interagisce con il dispositivo con una frequenza di circa 150 accessi al giorno, il che porta ad un input di dati diretto tramite l'interazione uomo-macchina. I flussi digitali possono essere registrati con l'aiuto delle tecnologie ed i dati generati possono essere successivamente utilizzati per l'ottimizzazione dei processi che andremo ad analizzare. La tesi presenterà e analizzerà l'importanza dell'utilizzo dei dati per l'analisi nel settore dell'agricoltura e, volendo dare un esempio tecnico più preciso, dell'integrazione dei dati meteorologici per l'irrigazione delle colture. Per fare un esempio concreto: nei giorni in cui è prevista pioggia sui campi, un sensore comunicherà all'agricoltore di non innaffiare i suoi raccolti e, di conseguenza, di risparmiare. Oltre a questa funzione sono pensabili diverse altre combinazioni e riassunte con il termine di "agricoltura intelligente".

C’è da sottolineare però che un approccio unico per tutti i tipi di agricoltura esistente nel mondo sarebbe troppo olistico e non eseguibile, poiché le proprietà da analizzare cambiano progressivamente ogni giorno, a seconda delle influenze ambientali e personali. Questa tesi volge all’analizzare l'uso dei sistemi di analisi dei dati per il settore agricolo in vari aspetti. L’idea fondamentale rimane sfruttare le prestazioni aziendali con l'aiuto dei processi informativi consentendo, attraverso l’uso dei dati per processi decisionali sofisticati, di facilitare il lavoro dell'agricoltore.

L'elevata variabilità e le molteplici fonti dei dati generati creano moli di dati su una scala molto grande; pertanto, ci riferiremo a questi risultatati con il nome di Big Data. Ciò è di grande rilevanza nell'ambito del settore agricolo, a causa della ricca informazione che va dall'input sensoriale delle macchine agricole, ai dettagli del contenuto del suolo, fino al comportamento della fauna selvatica dell'area in considerazione.

A partire da un'introduzione che descrive la necessità e l'importanza dell'analisi dei dati per i sistemi agricoli, seguita dalla revisione della letteratura sullo stato dell'arte la tesi propone un approccio strategico per gli agricoltori di unirsi alle piattaforme emergenti di condivisione dei dati. In conclusione questa tesi, attraverso un’analisi minuziosa del settore, vuole volgere lo sguardo a come un'agricoltura completamente connessa nel mondo digitalizzato potrebbe facilitare e soprattutto migliorare la produzione.

1. Introduction

1.1 The Context

Agriculture is the essential driver for any economy globally. Without a well-founded base of a functioning food supply chain, we citizens literally would have to take care on our own on a daily basis, cultivating and managing crops. Vice versa is the potential economic prosperity of any area depended on this fundamental layer, but on average the agricultural sector does not get paid as much attention to it as it deserves and it appears becoming taken for granted more and more. With any further ongoing generation, due to the high complex systems, operating smoothly in the background, almost invisible, but not (yet) automatic.

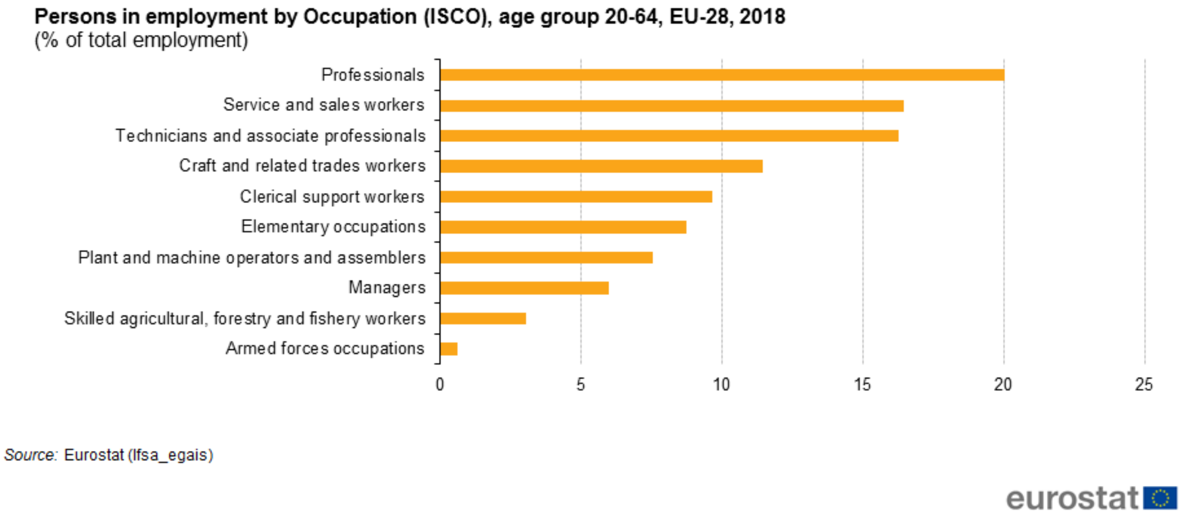


Figure 1 – Distribution of occupation within the Euro Zone (source: ec.europa.eu)

The statistic above, provided by "eurostat", is describing the employed persons, distinguished by macroscopic categories of the workforce, covering all known presented professions within the European Union. Interpreting the bar chart, solely 4 % of all workers within Europe are defined for dedicating their time towards Agriculture and its related fields, governing the food security. This point strengthens the importance, considering research and development undertaken to support the agricultural sector as much as possible, for creating positive externalities benefiting everyone´s life. Quoting George Orwell with the words chosen in his essay *"Marrakesh"*, where he criticised the imperialistic state of the society he perceived: *"All people who work with their hands are partly invisible, and the more important the work they do, the less visible they are"* (George Orwell, 1939).

Fortunately researches and young farmers across the globe understood the necessity of integrating the technological advancements we are already facing into farming. The most recent technological advancements which would come into favour of empowering a more efficient agricultural production, include the Blockchain Protocol, Artificial Intelligence, Data Analytics and the Internet-of-Things. (Stolwijk, Punter 2018, Poppe et al., 2018, F. Pabst et al., 2019). Combining these technologies smoothly, universal and interoperable, the vision of a *food-production-on-demand*, where food supply exactly hits food demand on a global scale, could be realized. The *Earth-over-shoot-day* 2019 *(overshootday.org)* was already hit at July 29, stating the point of time within one year, where the earth´s resources are exploited. If the global consumption behaviour is continuing like this, the risk is increasing of an extinct world due to "simple" overconsumption. The mathematical expression about this point of time is as following: $Earth\ Overshoot\ Day = \frac{World\ Biocapacity}{World\ Ecological\ Footprint} * 365$

Citing Papa Francesco: *"The fact that has shocked me the most is the Overshoot Day: By July 29th, we used up all the regenerative resources of 2019. From July 30 we started to consume more resources than the planet can regenerate in a year. It's very serious. It's a global emergency"* (Pope Francis, La Stampa, 08/2019). Headlines like this make the unobvious obvious, in the sense of, that human behaviour must change for reaching the United Nations Sustainable Development Goals (SDG), for guaranteeing a better tomorrow for the upcoming generations, and even for our own wellbeing. Indeed, technology will enhance the monitoring and documentation capabilities, collecting Data and Metadata, for tracking our own behaviour thus, quantifying the SDG.

Figure 2 - Sustainable Development Goals (source: un.org)

The SDG for itself got introduced as a blueprint, with defined goals how to achieve a sustainable future. They are set in order to be achieved by the year 2030, starting from its initial year 2016 by the UN. Surely these 17 goals in are co-dependent and interactive within each other. A lack progress on one goal might hinder the development of the others. For example, “Reduced Inequalities” cannot be achieved without “Gender Equality”, or “Climate Action” will go hand in hand with the goals 6, 7, 9, 11 12, 14 and 15, due to their correlative nature. But in terms of addressing the influential variables of the agricultural sector, these following would be the ones to be addressed by the agricultural sector (Loboguerrero et al., 2019): #1 No Poverty #2 Zero Hunger #5 Gender Equality #12 Responsible Consumption and Production #13 Climate Action #14 Life below Water #15 Life on Land.

1.2 Emphasizing of the importance of data analysis in agriculture

The Climate Change is one of the biggest upcoming potential threats disrupting the agricultural systems as it is known today. If the environmental conditions for the planted crops are not met during its lifecycle, the amount of yield is not going to be harvested as expected, which leads to declining revenues for operating farmers as well causing affected farmers searching for new work and abandon farming at all (Koemsoeun, 2020). Logically this causes complications along the food supply chain if the trend continues like this and should not be postponed until costs are recognized in financial terms. On one side the agricultural sector is directly affected by changes in the climate involuntarily due to the emissions issued by third parties, on the other side it is as well contributing to its alteration directly.

“Agriculture and climate change are characterized by a complex cause-effect relationship. The agricultural sector generates significant quantities of gas emissions that affect climate. The rise in the concentration of greenhouse gases in the atmosphere, the increase in temperatures as well as changes in the precipitation regime have repercussions on the volume, quality and stability of the agricultural and zoo technical production, but also on the natural environment in which agriculture is practiced.” (Agovino et al., 2019)

Statements as above are emphasizing the urge of change of existing systems for reaching sustainability as well in this sector, because food value chains are significant emitters of CO^2, contributing 19-29 % of GHGs global emissions, while facing the increase in global food demand up to 60 % due rising population and income growth (Loboguerrero et al., 2019). The imperative requires therefore crucial initiatives as well sustainable investments for adaptation and mitigation systems within the global agriculture itself as well the contextual food systems worldwide.

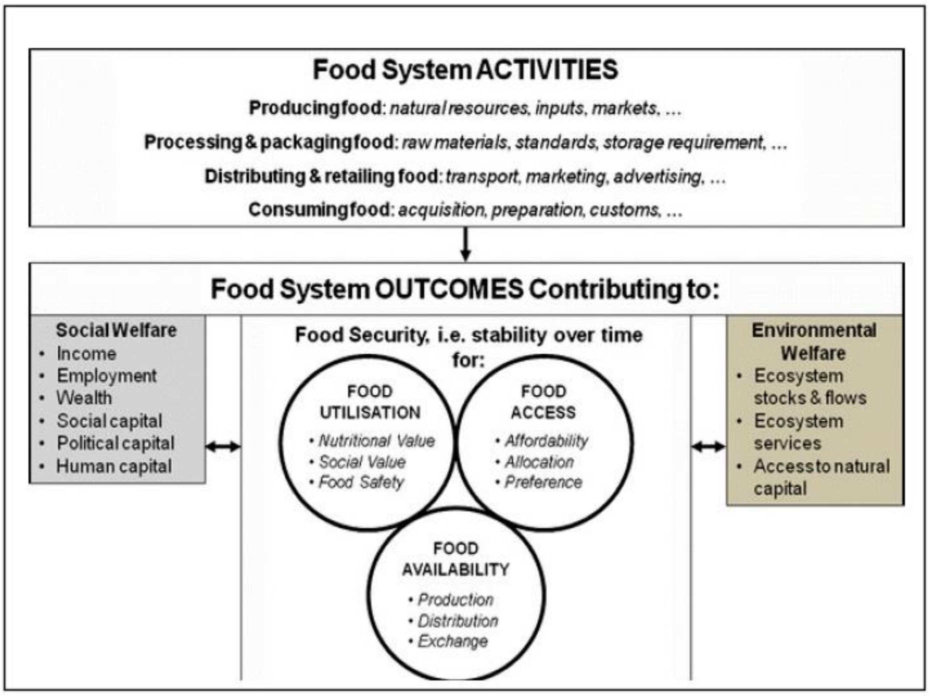


Figure 3 – The food system concept (source: A. M. Loboguerrero et al., 2019)

Above picture provides a simplistic conceptual model of food system activities and how the actors and activities are interrelated. It is a generic framework, applicable to ecosystems over the world and lightens various attributes, which are contributing to an interactive food system. The activities (producing, processing & packaging, distributing & retailing, consuming) necessary for a functioning food system are shaping the outcome of the overall system, affecting the 3 major pillars: Social Welfare, Food Security (utilisation, access, availability), Environmental Welfare. It is a network of multiple stakeholders with different intrinsic interests. If, for example, the diet of an ecosystem changes, then the to-be-produced foods also will change and probably also processing and packaging phase, until changes are noticeable at a natural capital level and/ or cause climatic/ environmental changes. An increase in crop output is until now mostly related with an increase of landscape in usage, which causes deforestation (or similar environmental changes) for making more productive land available.

This intervention will intervene in one way or another with the future outcome of the agricultural operations, due to multiple relations between crop and environment. Maybe also cause, yet unpredictable changes which could threat the overall food security system to collapse in a worst-case scenario. Weather forecasts are continue to become more and more precise, but every prediction which extends for now more than 5 days in advance, are regarded for non-credible. Or also diseases among plants and animals are thinkable to outbreak. Viruses and Bacteria keep evolving invisible, and become noticeable mostly too late, when the damage is already done. With this I want to say: agricultural farming in every manner is still a risky operation on a daily basis, facing weekly uncertainty about the outcome of operations up to the day, the crop is harvested, the milk and eggs are collected or the cattle is slaughtered, independent from further operations such as distribution and retailing the precious collected goods. It becomes especially risky when practices are continued, which are outdated like the excessive usage of antibiotics in animal fodder, plant pesticides and fertilizers. With continues iterations of operations it changes the biosphere and might foster the outcome it tried exactly to avoid – diminishing crops, antibiotics resistant bacteria, compositional changes in subterranean water, irreclaimable soil and produce many other, yet unthinkable tragedies. Especially the men made climate change will cause environmental changes with yet unpredictable outcome, which most likely will cause a chain of ripple effects and bares the potential to extinct most of the human race, nullifying its innovations, breakthroughs and all other achievements of mankind.

How already stated, farming is a complicated business, due to its multiple variables. Depending of the type of farming, it must deal with ranging from soils, crop types, cattle management, weather and rainfall predictions, nutrition and many others. Sometimes all the variables align, sometimes they don´t. Crop yields fluctuate, cattle don´t grow as expected and so do margins. The conventional methods not only have the potential to waste time and resources, they can also negatively affect soil water quality too, which causes unconsidered influence for the next generation of crops.

Data analysis enabled through digital technologies can help making the overall food systems related operations more responsive to external challenges and help them to work more smoothly internally. Data stems from various sources, such as topographic data provided by satellites, weather data predicting rainfall and sun exposure to specific times of a day or data from cameras and microphones recording cattle behaviour – all of them can be utilized to monitor the timely changes, depending from the technological resolution of the sensor.

Sensors (until now) can´t register changes on a biochemical level of observation, but the precision and accuracy they can do is already very good. The data serves as input for algorithms of various kinds. It can serve in a predictive manner for building simulations or analysing the status quo timely, which facilitates the decision making for solution-oriented outcomes, depending from the point of time of the situation. In the case for a wheat agriculture this could mean for example: sensors are registering if crops are stressed, algorithms are evaluating the data and depending from the outcome of the analysis, the algorithm suggests how much water, fertilizer and/or pesticide is needed to recover the crop, in the right amount needed. In principle it also has the potential to carry out the required operation automatically if automatized technology is available and integrated. Data and analytical algorithms are bringing science to the field and farm. Remote sensing technologies enable the farmer to make better management decisions.

The data produced, recorded and studied increases the effectiveness and accuracy for each following intervention. From iteration to iteration, the data pool of cases and scenarios is going to get bigger and bigger, which enables an archive of evidence based case studies, which might help to reduce the impact of external events disturbing the agricultural success in the future. With the help of data, benchmarks can be defined, such as Crop/yield, Water/m^2 or Agrichemicals/hectare. These numerical values help to measure the effectiveness of addressed issues. Optimizing the workflow towards the sustainable processes also diminishes the emissions footprint farming and agriculture is causing and therefore lowers the direct contribution to the climate change.

1.3. Research methodology

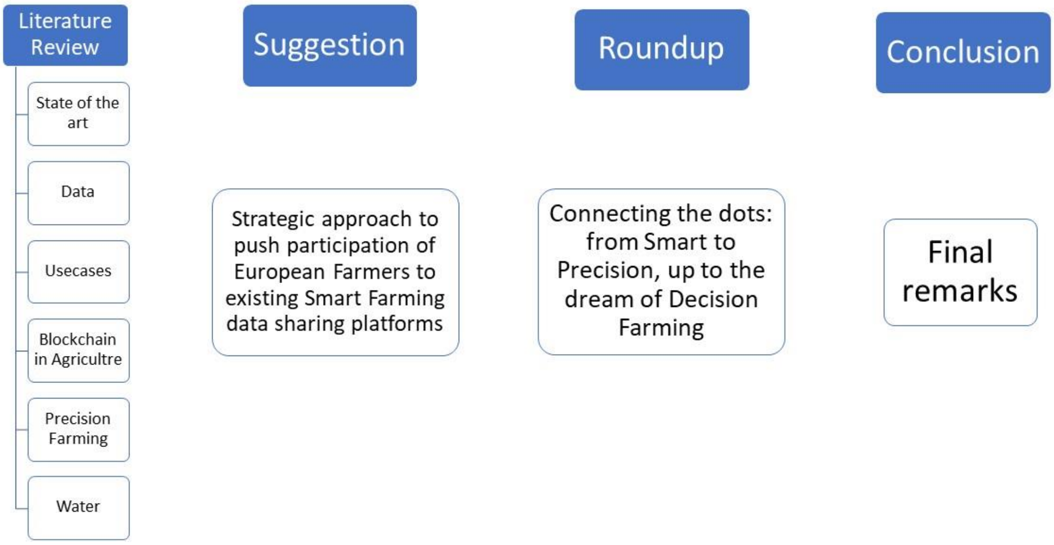


Figure 4 – Research methodology for this thesis

The underlying research methodology for this thesis is structured in following way (Figure 4):

The thesis begins with a broad, wide analysis of the existing knowledge extracted out of the available literature, covering the technological aspects related to smart agriculture in various fields of its discipline. The importance of this phase is to analyse and understand the technologies utilized in the emerging field of applications of smart agriculture, provided by products/solutions/results from the private, public and academic sector. The chapters in the literature review are arranged as systematically:

The chapter 2.1 "Introduction of the state of the art" will give a brief presentation of the technologies available, their underlying conceptual models, working principles which allow the employability in favour of the agricultural sector, for improvements of the sets of operations. Chapter 2.2 "Data" studies possible sources for public available data, an introduction of the data standardization issue, initiatives, trends and the inherent difficulties such as monetization and sharing. Chapter 2.3 "Case studies" will cover diverse pilot projects, stemming from different geographic origins. Field calendars are helping to monitor the farm to reduce complexity, which are going to be presented, as well their usage and endogenous benefits. Data analytics for crops farming and animal welfare are going to be presented as well. Finishing with observing the trends of automatic machinery and registered patents in smart agricultures.

Chapter 2.4. “Blockchain in agriculture” discusses the advantages the protocol it offers in terms of food traceability and food security. The technological design considerations of permissoned/permissionless will be presented as well. The chapter finishes with thoughts, covering the necessity of the blockchain technology as a fundamental module for enabling the theoretical concept of a smart agriculture into reality. Chapter 2.5 “Precision farming” targets the conceptual idea and progress undertaken within the fields of application of pattern recognition based on an usecase for Leaf Recognition, the benefits of the utilization of data analysis for on-field-agriculture (and its limitations), as well the usability of data analysis within agricultural greenhouses are going to be presented. Chapter 2.6 “Water” covers an evaluation of the existing water management systems. This section is from crucial importance, because besides a nutritious environment, water is the other fundamental brick for a prospering a plant. Without water, no life in any regard. Optimizations of water systems are also to be addressed for a sustainable environment. The concept of Crop Water Productivity as well Drip Irrigation systems are going to be presented, which deliver precious benchmarks for engineering and optimizations.

Chapter 3 is dedicated towards a solution-oriented strategy with the aim to push the participation of European farmers joining Data-Sharing platforms, based on Dr. Everett Rogers model “Diffusion of Innovations”, which regard in Management Engineering studies as a very descriptive model for understanding how innovative ideas and technologies behave over the course of time. This is from importance, because for now there neither exists any dominant platform design nor an observable trend, which would mirror the preferences of the operating farmers. Discussing this point is in the authors perspective from crucial importance, due to the fact of farmers reluctance towards innovation and especially the interaction with the Data-Sharing platforms as a gateway for the potential synergies between agriculture and data-analysis. If no smart agriculture and data sharing practices are starting to be integrated, the overall agricultural ecosystem increases the risk to collapse, due to the so called “Tragedy of the Commons”.

The idea behind the tragedy of the commons stems from an essay written by the Biologist Garett Hardin in 1968 and describes the generic situation in a shared-resource system, where the individual actor responds independently according to its own self-interest, depleting the shared resource. But indeed this represents a behaviour contrary to the common good of all actors, where everybody would benefit by showing solidarity and acting collectively, contrary to following self-interest. In the case of agriculture a sharing of data could mean increasing each others crop/animal productivity, without antagonize each other farmers business. The reluctance of farmers to enter any platform and share their data is hindering the likelihood of entering the century of a smart agriculture, concerning small-medium sized businesses.

In Chapter 4 the overall conclusion of the thesis is going to be verbalized and providing a vision of the authors opinion about the agrareconomy of tomorrow, once the social-technical obstacles are overcome and a fully interconnected/deterministic network of the participating actors in agriculture is realized. The dots between previous discussed aspects are going to be connected, presenting the idea of transforming the agricultural sector in its existing form, where farmers are seen as individuals evolving to precision farmers, where the targeted yield of output is going to produced, up to an intelligent network of interacting nodes in a sustainable manner, where the overall system is creating more value than the sum of each individuals participation. Finishing with the conclusion of the thesis, where final remarks are going to be presented.

Strongly in the literature review information has been gathered from web-based providers and search engines such as Elsevier, Scopus and Google Scholar. Keywords in different set of combinations have been used for finding the articles, which have been utilized in the work. The most used keyword was “smart agriculture”, in combination with the other keywords “IoT”, “animal welfare”, “precision farming”, “water management”, “data standardization”, “reluctance data sharing”, “pattern recognition” and “big data”. In a few parts of the work, self-defined benchmarks are going to be presented. These have the function to spark the imagination, how the intangible asset data can be used for numerical benchmarks, representing vividly the effort undertaken in agricultural.

2. Literature Review

2.1 Introduction about the state of the art

At the beginning a brief introduction of the fundamental building bricks is necessary, which are allowing to utilize the integrated digital technologies within the agricultural network of machinery, for processing the sophisticated analysis in order to enable the infrastructure for a smart agriculture.

2.1.1 Processing systems

Hardware includes the touchable sub-parts such as the case, central processing unit, storage systems, graphic and sound card - physically interconnected via the motherboard. Each computer differs in principle from each other depending on the architecture and the running software. The hardware is mostly directed by the software for executing any command or instruction. A combination of hard- and software forms the commonly known computing system, but also only hardware systems are thinkable which solely execute arithmetic computations and deliver back the output.

Software consists of encoded information, in contrast to the physical hardware, from which the system is built upon. To simplify, Software is a collection of instructions which is given to the processing unit to perform a specific task. The unit for processing is expressed in Hertz, which expresses how many cycles per second the underlying hardware can process. It performs very detailed functions in order to satisfy required needs, for example database management or complex calculations. It does so, by compiling the inputs with the help of the source code into binary digits. The syntax of the source code is depending from the programming language the software program is written and in the realm of Data Analysis the most common used are: C++, Python and Java. Software programmes can help the farmer to simplify processes, which elsewise would have to be done manually by the farmer him-/herself.

Cloud Computing describes the on-demand availability of computing system resources, especially targeting data storage and computing power, which does not need any directed active management by the end-user. The overall term is used to describe data centres, which are available to many users via technical interfaces and communication protocols such as the Internet. Cloud computing relies on sharing of resources to achieve coherence and reduce costs. Different providers of cloud computing systems are existing and the incumbent digital technologies providers such as Amazon, Google or Microsoft are very dominant as service providers.

Internet of Things – IoT is the collective expression for a global infrastructure of virtual objects, which are connected to each other via the internet. It allows interaction between humans and any electronic system, as well solely the systems with themselves. These may be equipped with small chips, sensors, data storage devices or also even software systems, which enable a data exchange with one or more other objects. Due to this interconnectivity they have the possibility to regulate/adjust/correct interactively towards given values or benchmarks and allows time-real monitoring. In smart agriculture this could mean an increase of automatization and reduce the need of human intervention.

2.1.2 Data analytics & Artificial Intelligence

Data is generally understood to mean information, either numerical values or formulable findings, that can be obtained through measurement or observation. A set of data is best understood within the specialized context from source of origin, meaning a set of data has its own distinct interpretation depending from the environment its generated from. To give a more precise example stating above written part: The same "data set A", gathered by observing the behaviour/characteristics of potatoes, would have a different amount of utility for tomatoes and vice versa in the opposite case. Data, generated through external objects, will be the raw input for applications designed for the smart agriculture.

Data & Big Data Analysis uses statistical methods to extract information from the data collected. Big Data Analysis describes the process of collecting and analysing large volumes of data to extract information, in order to discover hidden patterns and connections between data previously collected. The name Big Data stems from the nature of the large volume of the analysed database, its data type variety and the velocity of data-generation. Therefore, it requires a higher amount of processing resources, or distributed computing, in comparison for “simple” data analysis in the same time. A farm is producing a lot of data, stemming from various sources, with yet unknown correlations and interdependences. For example: the farming of potatoes on a field will cause a change in the nutrition of the soil. Analysing the recorded data would require a lot of time and human resources, if each time a manually designed algorithm would try to extract knowledge out of the different data sets, which are despite of their source also very voluminous. Big data analysis facilitates the findings, or non-findings, of potential cross-correlations between different data sets, more specifically explained in the section “Data Mining”. They can then reveal orientation for further analysis, with the aim of finding content rich of knowledge depending from the objectives of research. Objectives in the progressive interest for the agricultural sector could be for example to improve efficiency, sustainability and food security.

Artificial Learning (AI) is an area of computer science, dealing with the automation of intelligent behaviour and machine learning. It is a very blurry definition insofar, as there is no precise definition of intelligence itself. Nonetheless it is used in research and development and distinguishes between strong and weak AI. A simpler definition of AI would be, any program that can sense, reason, act and adapt. Machine Learning and Deep Learning are considered as branches of the overall category of artificial learning, which are described in the following.

Machine Learning is a division within the realm of Artificial Learning. The artificial system learns from examples/experiences and can generalize these after the end of the learning phase. For doing so, machine learning algorithms build a statistical model based on training data, meaning the examples are not simply memorized, but patterns and regularities are recognized in the learning data. Obviously, this allows a wide range of possibilities, ranging from automated diagnosis algorithms, detection and classifications. It improves its performance by repeating the same task over and over again with slightly optimizations by the help of introduction of relevant features and weights, for making determination or prediction of new data. In a nutshell:

The process of machine learning facilitates the speed of deriving meaning from all the collected data sets and can adjust the results by filtering relevant data sets for further improvements, thanks to further exposure of data over time.

Deep Learning is a further subfield of machine learning, in which multi-layered neural networks learn from huge amount of data repetitive. The process is inspired by the structure and function of the brains neural networks, therefore called artificial neural networks. The learning will occur either in supervised or unsupervised form. Supervised learning occurs when deep learning model learns and makes interferences from data that has been already labelled. Unsupervised learning contrary, occurs when the model learns and makes interferences from unlabelled data. The neurons, responsible for the processing of the data, are organized in different layers, which distinguishes between input, hidden and output layer.

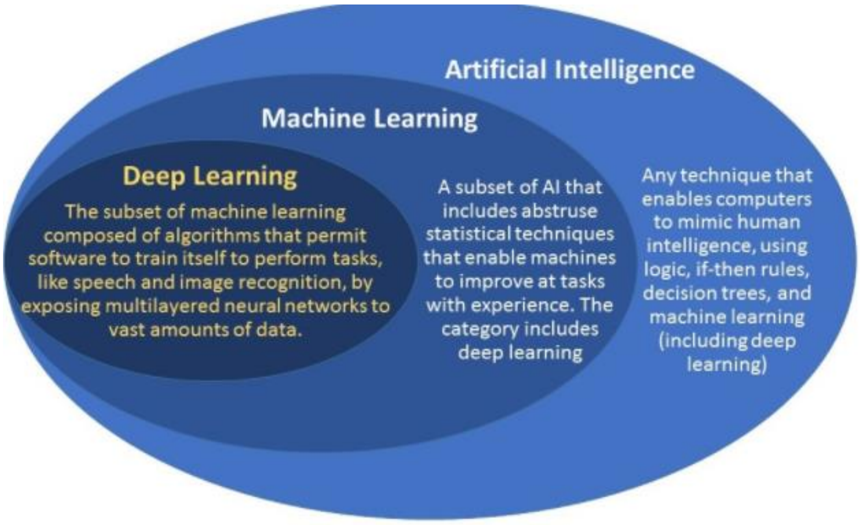


Figure 5: AI and its subdivisions, ML and DL (source: https://www.deeplearningitalia.com/a-gentle-overview-on-the-deep-learning-and-machine-learning/)

Different fields of applications of smart agriculture would require different types of learning algorithms. If a machine is aimed to execute repetitive tasks, it would be from advantage to use supervised learning. In the case of unsupervised learning this could lead to fatal errors and huge costs. Whereas if an unstructured bulk of data is going to be analysed automatically, then an unsupervised learning algorithm would be helpful. Due to its unbiased execution of analysis to the to-be-processed data set, it can be able to find correlations which the supervised algorithm would else miss eventually.

Depending therefore for specific use case in agriculture, one or another learning algorithm is favoured to be used for prospective outcome. In a nutshell: where repetitive tasks are wished to be optimized, a supervised learning algorithm would be useful. Whereas no executive action, such in analysis is going to happen, an unsupervised algorithm would be helpful, in order to enhance the farmer decision making.

After the construction of a **Neural Network**, the training phase follows in which the network learns, using the methods of: 1.) development of new connections, 2.) deleting existing connections, 3.) changing the weight from neuron to neuron, 4.) adjusting the threshold values of neurons in case they carry any previous value, 5.) adding/deleting whole neurons, and 6.) modification of activation. Additionally, the learning behaviour changes when the activation function of the neurons or learning rate of the overall network changes. A network learns by modifying the weights of the neurons accordingly towards the previously stated objectives for the output.

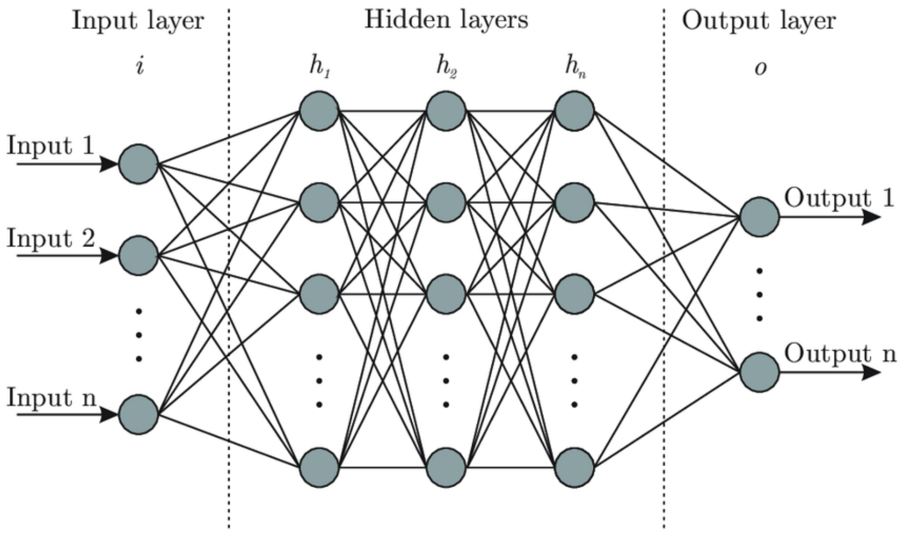


Figure 6: Architecture of a neural network (source: https://www.researchgate.net/figure/Artificial-neural-network-architecture-ANN-i-h-1-h-2-h-n-o_fig1_321259051)

The usefulness of Neural Networks relies to approximate functions, that are generally unknown. To be compared like black boxes, which can be trained, and results can be measured, but the actual decision path, how the network concluded from the initial inputs to the measured outputs, is mostly hidden, due to the continues re-arrangements of the neurons in the hidden layer. Neural networks can be hardware- or software-based and can be arranged to a variety of different topologies and learning algorithms, which makes neural networks distinctive from each other.

Imagination is the only limit determining, how to wire the network and measuring the results afterwards will give clues about the effectiveness of the previously defined wiring. But already some clusters appear to show evidence, that specific networks are better suited to approximate yet unknown functions better than other type of networks, depending from their internal wiring. Figure 6 represents the generic "Deep Feed Forward" neural network. Its usefulness for specific defined tasks, for example "controlling if a cow needs to me milked" can only be evaluated after initial trials have been run, if its approximation was correct, which needs the evaluation of experts to cluster "correct" and "wrong" outputs. This technology is very young, and a lot of more research is needed, to evaluate the outcome, impact and ethics of neural networks. But for now, it appears as already definitive, that neural networks have the capability to outperform humans cognitively. In the smart agriculture this could mean as a supervising instrument, which monitors all the processes (considering the farm as a to-be-approximated-function in a whole) or also individual workflows (*"does the wheat needs to be watered? If yes, how much water exactly, to avoid flooding?"* or *"how many pigs are now at the fodder drought? Does more food needs to be put into the drought?")* in order to help the farmer, in his decision making processes to reduce the likelihood of errors to occur. Also a fully automatization of repetitive tasks is theoretically possible. Nonetheless, a neural network can principally also become programmed against the interest of the operator, due to the hidden layer network operations. A lot of attention is going to be required when dealing with neural networks, independent of the application. Its prospective is as promising as potentially threatful.

Data Mining means the systematic application of statistical methods to large databases (Big Data) with the aim of recognizing new cross-connections and trends. Due to their size, such databases are processed using computer-aided methods, such as Neural Networks. In practice, the sub-term data mining was applied to the entire process of so-called "Knowledge Discovery in Databases", which also includes steps such as pre-processing and evaluation, while data mining in the narrower sense only denotes the actual processing step of the process.

The title data mining by itself may appear misleading, because it is derived from gaining knowledge from existing data sets, and not about generating data itself. In a scientific context it primarily refers to the extraction of knowledge, that is valid in the statistical sense, previously unknown and potentially useful, which could discover certain regularities or hidden relationships.

The overall goal of data mining in the best case scenario would be the discovery of specific patterns, respecting the acceptable constraints. The employability in the agricultural sector could enhance disclosure about circumstances, which hinder the farm in its operating outcome, which remained until observation unknown. Or also an analysis of the workflow processes may lead to optimizations, to reduce costs, increase sustainability and/or increase margins. The limits of data mining are primarily the to-be-available data sets, which are depending from quantity and quality of the employed sensorics system.

This thesis is built with publications of academic papers and other relevant articles, published in the majority of cases within the past year 2019, and a minority within the year of 2020. This consideration has been chosen simply by the fact, of the high paced alteration of technological progress. Technologies and methodologies which may have been relevant in previous years may not be from big relevance anymore today and to reduce the probability, this preselection of search have been undertaken.

2.1.3 Cybersecurity

The scope of **Cybersecurity** can be presented as a set of techniques in order to protect the confidentiality, integrity and availability of computer systems, networks and data against potential external threats. Confidentiality means that only authorized people should be able to access or read specific computer systems and data. Integrity means, that only authorized people should have the ability to use or modify systems and data. Availability means that only authorized people should always have access to their systems/data and deny access to those who should not. Authentication is the necessary process for ensuring, that the user is who it claims to be, by asking for the unique user-identity and the matching password. Authentication is important, because it enables organizations to keep their network secure and permits only authenticated users access to its protected resources. If no digital secure mechanism is given, then the risk is high for failure or refusal, due to lack of trust for the positive externalities. In smart agricultures this potential threat could mean, that an external attacker could manipulate the data, algorithms and other communication interfaces in any thinkable manner and disturb the workflow processes of the interconnected devices. As many different computing systems are existing, so in theory, as many different security systems would be necessary to implement for guaranteeing full security.

Quantum computing systems may cause a complete shift in cyber security and make all achieved efforts ineffective, once they will be commercially available. Especially in the realm of IoT it might be difficult to align on a common security standard, due to the interconnectivity for billions of devices, with more connected devices to be expected from different producers all over the globe.

This trend bears the risk of introducing and increasing a myriad of vulnerabilities across each layer of the IoT ecosystems. The applications running on these devices has to be managed, protected and maintained securely. Security at connectivity layers should be in place as well, regardless of the connectivity type (Wifi, satellite, public/local/private networks).

A recommended one-size-fits-all solution does not exist yet and there are many alliances introducing their concepts for implementations which help to ensure a multi-layered end-to-end approach to guarantee security between the network of IoT devices. For smart farming it will be very important to align on common standards, but on the same side it is a difficult task to be realized, finding agreements in a globalised interactive economy. The IOTA-foundation aims to introduce an international, quantum-proof security protocol for communication across IoT devices all other globe with their Open Source approach, but probably a coexistence of different protocols will be observable in the near future.

2.2 Data

In agriculture until now, data and knowledge has been mostly treated in a conservative manner where it has been passed from one generation to another, or at least to the closest colleagues due to the underlying competitive pressure of the business. As well is the usefulness of any data set in any form very dependent from crop and geographical location. Due to the constantly changing environment in which farmers are operating, especially of the increasing magnitude of impact originating from the climate change, the usability for the data set of today could change literally overnight and therefore nullifies its reliability. Indeed, the value of data gets increased by combining data from different sources and has through this approach the potential to reorganise food chains (Poppe et al., 2018).

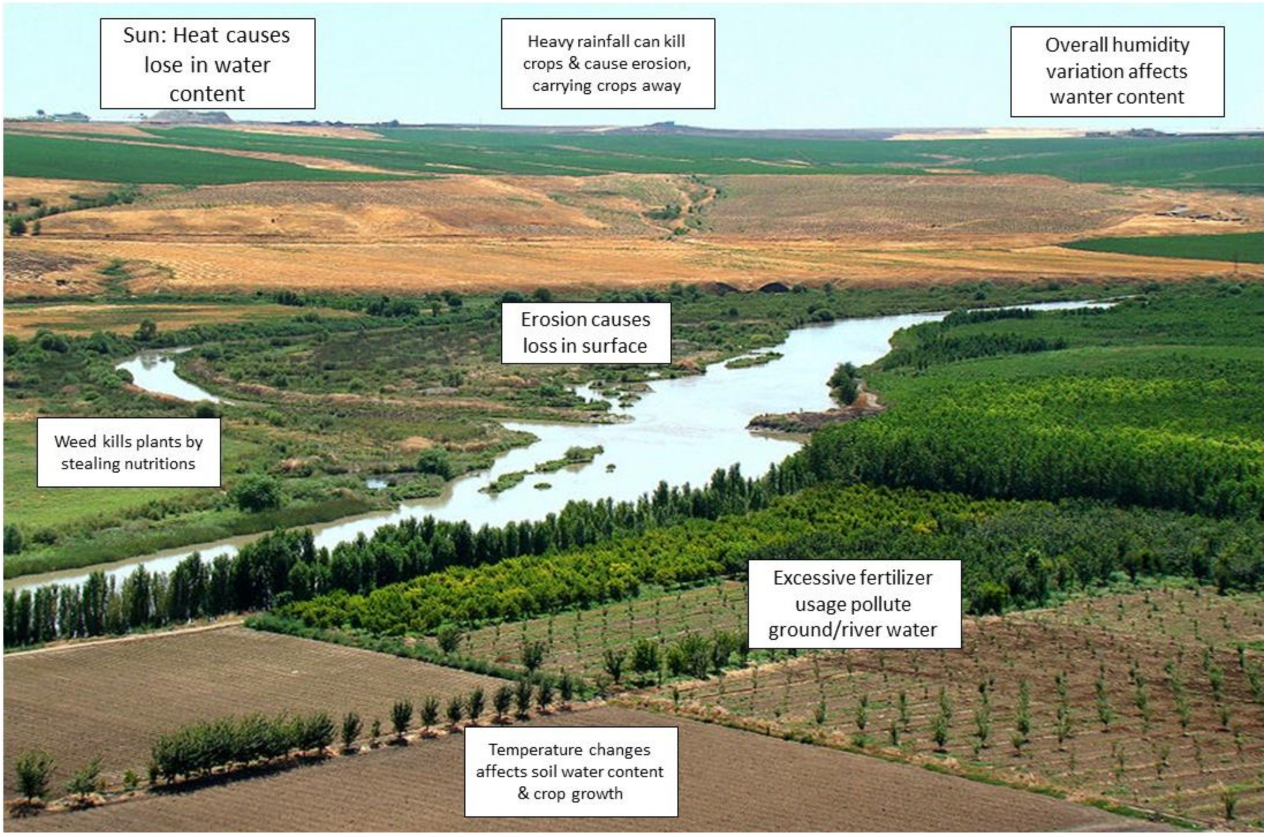


Figure 7: Various determinants influencing agricultural performance (source: https://gatesofnineveh.files.wordpress.com/2012/02/781px-tigris_river_at_diyarbakir.jpg - edited by the author of the thesis)

Figure 7 shows variables which alter the environmental states interdependently. It gives a glimpse of the complex interactions, which especially outdoor agricultures are facing and might hinder the anticipated yields. Extensive heat for example causes lose in water content of the ground. If a heat wave continues over days and the plants are not watered, firstly they might die and secondly, the ground may harden so strong that even in the case of water supply, the water would just roll off. An excessive fertilizer usage may increase the growth of weeds, which are then killed with pesticides. Both chemicals will trickle down to ground water and cause somewhere, something else. The actions undertaken by Farmer A could have serious impact on the outcome of Farmer B´s agriculture and vice versa. This picture gives a glimpse, how complicated farming is, and digital processes can help to reduce the complexity of the interrelated processes farming is facing in order to reduce costs and risks, by determining the external variables as detailed as possible, which are then available for data analysis.

For a solution oriented, collaborative interaction and increasing each participant benefit, it would be from advantage to agree on common notions within the data space of agriculture. In the following paragraphs following topics are going to be analysed: Public available data sources and an introduction to data standardization organisations, inclusive a description of its inherent difficulties. This chapter finishes with the residual data sharing issue between farmers. This is from crucial importance due to the slow rate of adoption of farmers, joining currently any of the existing or emerging smart farming platforms provided.

2.2.1 Public Available Sources

Integrating Data sets from different sources have the ability increasing the reliability and usefulness of the collected data set (Stolwijk, Punter, 2018). Especially data and data analysis has in the realm of agriculture the strength to improve the executed processes in several manners. Depending from the objectives of the individual farmer, they can range from increasing sustainability, reducing agrichemicals, increasing crops, reducing labour costs, enhancing biodiversity or increase margins. Independent from the integration of sensors on the farm, the farmer has in principle the opportunity to access public available data. If the agricultural enterprise would consider for example if rainfall is going to be expected covering the hectares, then the farmer could save a) water expenditures and b) the operational costs (gasoline, labour, depreciation of the tractor). Elsewise the farmer would spend time and effort, watering the crops and on secondly, additional rainfall then could bear the risk to overwater the crops or even carry them away from the ground. Data sources, revealing information about the environmental events are existing and mostly free from any cost. In the realm of public available data sources, analysts and farmers have several options to access datasets from relevance to be utilized within their models, but I would like to introduce for now following 4: OpenWeatherMap (Weather API), the Copernicus program, the data access hub Eumetset and as well, Google Earth.

Weather API is the user-friendly application programming interface offered by the host **OpenWeatherMap.org**. It offers free access of some of their provided data sets, if the request rate is lower than 60 requests/minute, but as well different pricing models which offers more entailed service provision. The data sets include various weather and climate relevant data, such as hourly/daily/monthly forecasts, historical weather data, pressure, temperature, wind direction, air pollution, soil temperature, , precipitation of any kind, geographical colored weather maps, tailored to the geographical position of request. Regarding the website provider OpenWeatherMap.org, the data is combined by Weather Services and Satellite imagery, offered in the formats of XML and JSON.

The **Copernicus** program is the earth observing program governed under the regulatory body of the European Comission, with the aim to collect, store and analyse data, provided by a network of in total 6 satellites, the so-called Sentinels. Other third party satellites are contributing to the overall space mission as well, but the 6 Sentinels are in ownership by the different stakeholders in the European Union. It sets its main mission to monitor mother-earths ecosystem, in order to reduce the potential threats caused due to natural or man-made disasters, such as forest fires, earthquakes or polluted air/waters. In the process of the data gathering, also sensors placed on seas, the land and in the air are contributing to provide a diverse and large amount of reliable up-do-date information, which are currently 12 terabytes per day. These are available in the archives for up to 14-days and accessible through different Data access hubs, such as Eumetset for example, which is going to be presented later.

The data sets are available to be used for the creation of statistics and topographic maps and already analysed for researches (or other end-users) in useful indicators, providing information about past times, the present and future trends. Due to the public service framework, access to the data sets is free of charge. The observing systems are set to record interrelated topics, which are: atmospheric, marine, environmental and land monitoring, climate change, emergency management and security. Concrete areas of applications provided by Copernicus concerning the environmental analysis, would be for example the analysis of the aerosols content, which is known for destroying the ozone layers. The Copernicus framework is also regularly evaluating the melting of the polar ice caps, the monitoring of the air and water quality, but also ocean and deforestation levels. In one short sentence: Copernicus is using space data, merged with other sources of information, to increase the situational awareness of the planet earth. For the agricultural sector data sets are from relevance, which are studying the irrigation of the fields, tracing the outbreaks of diseases and monitor the crops for smarter food management. Also complementary for the relevant data sets of agricultural services would be analysis of desertification/deforestation of the area around where agriculture is executed, due to the interrelation of biodiversity losses and its effect on the ecological system. Sentinel 1, 2, 3 and 5 are already in the orbit, and the launches for the other satellites 6 and 4 are going to be expected in the end of the year 2020 and beginning 2021.

Eumetset, short for ***Eu**ropean Organisation for the Exploitation of **Met**eorological **Sat**ellites*, is the intergovernmental agency with it headquarter in Darmstadt (Germany), established to join forces of 31 European member states together in order to develop and exploit meteorological satellite systems. It has sets to its own mission to deliver the best observations possibilities for weather forecasting and monitor the impact of the climate change in various aspects, by taking advantage of the satellites submitted in orbit via the Copernicus space programm. The satelittes of the Copernicus network are differing in a technical manner and due to their technological differentiation, Eumetset is able to exploit data for doing integrated forecasts from various reliable sources and semantics.

The network of satellites observes and collects data sets regarding, atmosphere, marine environment and land monitoring, biologic growth, as well observing emergency management, security and the climate change. These data sets are then able to be used in order to make statistics as well topographic maps.

The data is provisioned in the XML format, and able to be streamed via the Eumetcast software program, in a nearly live time frame. Besides of their own sensorics network in the orbit, Eumetset collaborates as well with the space air programs from the United States and India, for enhancing the service level offered. In terms of design it orientates itself towards its prospective user and enhances the interface design for increasing continuously the product experience.

Eumetset also employs scientific researchers and provides therefore peer-reviewed academic publications. In overall it can be said, Eumetset is a futuristic, financially independent european observation system performing at the technological status quo, by exploiting and leveraging the Copernicus infrastructure and its geographic information services. By its user-centric driven organizational approach it delivers precious data sets in the XML format for providing accurate and precise weather forecasts in the smallest detail possible, as captures the dynamics of climate changes on a long term timeframe, which enhance the accuracy of policy makers for future decision processes.

Google Earth is a software from the US company Google LLC that represents a virtual globe. It overlays satellite and aerial images of different resolutions with geodata and show them on a digital elevation model of the earth. The basic form of the software is free of charge and available for all known computational operating systems. It covers 98 % of the overall earth and has a rich history of data sets. It utilizes own satellites and sensor systems for monitoring the state of the earth, but as well accesses data provided by the Copernicus network for the provision of a broader database and therefore increases the accuracy of the overall performance. Users, mostly addressed towards scientists, have access for own usage of the data sets via earthengine.google.com, provided by the Google LLC as well.

Earthengine.google.com offers a geospatial data processing and analysis platform, powered by an existing data centre infrastructure, powered by Google itself. Therefore, it allows scientists focusing fully on their field of research, due to the simplified access of the data. The datasets cover: landsat data with a history of 40 years, Copernicus Sentinel data, Non-satellite imagery (elevation, land cover, topography, vector and climate data). It includes the possibility of uploading the own data sets and the possibility of sharing them if wanted.

The website offers a full featured development environment as well in the languages JavaScript and Python. Additionally, it offers several features, such as visual changes over time in time-lapse, and machine learning. The database is very rich and technological sophisticated, which enable several, customizable use cases. It does not focus on specific weather forecasting usage or climate change monitoring as the previous 2 examples but offers due to its organizational structure a hub for the scientific research community active in the field.

Figure 8: openweathermap.org
(source: openweathermap.org)

Figure 9: Copernicus
(source: copernicus.eu)

Figure 10: Eumetsat data access hub
(source: eumetnet.eu)

Figure 11: Google Earth Engine
(source:earthengine.google.com)

These publicly available data sources are enabling researchers and eligible programmers to build primarily models, which can describe approximations of the farms surroundings. An analysis of the environmental variables can help to make smarter decision making on a daily basis, but also for future decisions. In combination with more detailed data, stemming for example from the farms operations inside, they are a helpful complementary source, helping finding the individuals farm to find its individual sweet spot.

2.2.2 Data standardization issue, its difficulties & standardization initiatives

Data itself can be stored in any technically feasible format, but for now there is not existing any standardized type, which would enhance reading and interpretation possibility. Unfortunately, it could not be found any specific format for data storage, utilized in agricultural applications. Seemingly every provider of data is publishing the data in their preferred format. But in the following the most popular ones are going to be presented. In the following I would like to describe briefly the for now 4 most popular ones (JSON, PMML, XML, DICAT) regarding the trends, continued by further description translation of data formats and initiatives for data.

JSON stands for JavaScript object notation and is a compact data format, serving the purpose of data exchange between applications and storage of structured data. Especially in web applications and mobile apps it is often used, due to its syntax of JavaScript and allows a dynamic relationship between the requesting client and the providing server. For character encoding JSON uses primarily UTF-8, but as well UTF-16 and UTF-32 are applicable. Principally JSON is based on the object notation of the JavaScript language and its standard only, but it does not require JavaScript to read or write, because it is made in text format which is language independent and can be run everywhere. JSON notation contains these basic elements: Objects, Object members, arrays, values, strings and null.

XML is short for "Extensible Markup Language" (XML) and as computer language in usage for the presentation of hierarchically structured data in the format of a text file that can be read by both, humans and machines. One of the advantages of this type of data format is the implementation-independent exchange of data between processing systems. Due to design of simplicity, generality and usability across the devices, the language can be used as a representation of arbitrary data structures, which then required to be refined by data mining.

Due to the platform communication independence of XML, it does not create switching costs for any prospective participant to interpret or send data in this UTF-8 encoded storage type. With the help of simple tags, the organizational structure of hierarchies is enabled and simplifies the handling of data for further applications.

PMML, also known as “Predictive Model Markup Language”, and a data standard promoted by the “Data Mining Group”, a non-for-profit organization founded in 2008, which aims to set being the standard for data mining. PMML is due to its structure well suited for describing and exchanging predictive models, produced by data mining and machine learning algorithms. The advantage of PMML is, that is offers interfaces for various data mining and analysis tools, because of the continuous improvements it could reach since the first version publications in 1998 and adoption of over 30 middle to big sized corporations, such like Microsoft, IBM, SAP and Oracle.

DCAT is the short expression for “Data Catalog Vocabulary” and aims a design to simplify the interoperability between existing data catalogues. This format got introduced by the W3 Consortium, with the goal to create a smooth interface between the IT and the Business world. With this approach, producers enhance the transparency of data’s origin, as well allow their programmes the usage of metadata from multiple catalogues to increase the validity of their prospective analysis. It helps to see potential correlation between different types of Meta-Data and enable a preview, before streaming it to confirm the complementary characteristics it may offer or disprove the usefulness in the opposite case. Through this approach, the digital retention of aggregated metadata is facilitated in case of privacy concerns of the individual data producers, who may not want to expose all their available data but some of them.

Until now there is no dominant or preferred data standard observable, but a transformation between different data formats is indeed possible, called simplistically: Data Transformation. Depending from the required changes from the source and target data, the overall volume, manual or automated processes, the overall procedure differ with complexity. ETL processes, or also known as “Extract – Transform – Load” processes, are offering a holistic approach for the data warehouse management overcoming this hurdle. The most famous programs, stemming from the field of Open-Source Softwares, are *“Kettle Pentaho Data Integration”,* “*Scriptella ETL*”, “*CloverETL*”, *“Talend Open Studio”,* and “*Catmandu”.* The benefits of this valuable approach are multiple. It increases the value of the overall data, organized and centralized into a single repository. The first step includes, extracting data from an array of sources, the second is achieving standardization, deduplication and verification, and the last step takes care of extracting the data into the new targeted location.

It is superior than hand coding the data, because hand coding would cause different coding techniques and as well require a higher maintenance cost. Every individual usecase for Data Transformation would mean a customed integration technique, depended from the underlying hard- and software of the systems operator. Cloud compatibility would be from overall advantage for a smooth operation of the overall process to increase the business intelligence.

Different organizations are aware of the lack of a data standard which would be very useful for improving operations. Boris Otto and his colleagues from the International Data Space Association, are making following statement: "Data analytics/artificial intelligence and business process automation require an ever-increasing wealth of data. To remain competitive, organizations cannot just use internal and publicly available data sources, but need information also from external individuals and organizations. As, e.g., supply chains evolve into highly flexible supply and demand networks, much of the required data exchange cannot be prepared any longer by lengthy human negotiations but must be semi-automatically negotiated, executed and monitored for contractual and legal compliance." (Jarke, Otto, Ram, 2019). The International Data Space Association set as an objective to become the standard for the trade and exchange of all kinds of data assets, while holding data sovereignty, to foster adoption rate and accelerate data economy at a whole.

If International acting organizations would agree on a common format for the data standardization on an international scope, then it could facilitate finding a solution for the outstanding monetization problem of data as well. Regarding many consultancies data is regarded as the new oil and a could entail new revenue streams for all the acting operators within the value stream chain "The exploratory analysis of regulatory instruments should be taken further towards investigating the interdependence among these instruments and between them and market oriented instruments (such as pricing)" (Jarke, Otto, 2019).

Not pushing efforts to the standardization process of data formats, but another organization worth mentioning in the realm of introducing industrial standards is the "Object Management Group", short OMG. OMG has gained a lot of experience in terms of publishing ISO standards and exists as an organization since 1989. The CEO of OMG Richard Soley is holding a chair as member of the Supervisory Board of the Iota foundation.

The Iota foundation is a non-for-profit organization, which set as one of their objectives, introducing the open-source protocol for the Internet-of-Things. Additionally, the Iota-protocol has an own cryptocurrency, the Iota-Token, which could serve as unit of exchange for the data economy. It is decentralized, scalable and as well follows an open source design, with the aim to include as many economic participants as possible, independent from their size or sector. In December 2019 the Iota foundation announced a collaboration with the Future Farm consortium in Norway, for building a Smart-Farming platform around the Iota protocol. The idea is to use the tangle (not a blockchain, but a distributed ledger technology as well) in the dairy industry. It monitors the whole production cycle literally from the grass roots up to the sold milk. The data can be gathered all along the way, captured by tiny IoT devices and stored in the tangle. Starting from the quality and origin of the grass from the fields with which the cows are fed, over to data in every thinkable manner considering the cows themselves and finalizing with storing data concerning the purchase process of the milk. The real challenge is how to integrate the solution along the full value chain of the farmer and the following stakeholders involved. It is a difficult act to engage all actors, convince them to share the information and integrating it into a system, which can track all the input of grass fields (like fertilizers) up to information of the final product, the milk. The data surely must be transparent on a ledger, but also the exchange in between is relevant. If the exchange fee of data is greater than the intrinsic value of the data itself, then a transaction is very unlikely to happen. Indeed, regarding the IOTA foundation itself, the exchange of data is considered without any fees, due to their ledger topology the tangle, which differs from the widely known blockchain protocol. The gathered data can be used for example to reduce the methane gas emissions produced by the cows via optimizing the environmental variables of the field, where the gras is growing. Other big participating partners within the project itself are the Norwegian University of Life Sciences, the fertilizer company *Yara* and the food analytics laboratories group called *Eurofins*.

2.2.3 Data sharing issue

Regarding the World Bank Group, data sharing and open data initiatives have significant potential to provide benefits such as other global commodities. It allows individuals, organizations and even governments to innovate in cross-border collaboration. Through this pursue, following aspects are benefiting from an open data approach: transparency, public service improvement, innovation and economic value and efficiency (World Bank Group, 2019).

Statements as above picture the overall benefits of an open data approach. But surely not everyone is a philanthropist who is willing to give and share the generated data for free. Data is not without any reason considered as the new oil for the upcoming Industrial Revolution. (World Bank Group, 2019). Digital technologies and big data applications are social-technical, meaning that they are a product of the relationships between people, technology, institutions, social and legal actors. A solution to fill the gap between farmers and digital technologies can be presented by Smart Farming platforms.

The number of Smart Farming platforms is emerging and they offer farmers an improvement of their underlying business, but for any realization of the ambitious results, certainly the sharing of the produced and collected data is required. This is still an obstacle, because of farmers reluctancy to data sharing (Wiseman et al., 2019).

To mention a few existing smart farming platforms, following ones are based and operating in Europe: 365farmnet.com, Smart-akis.com, join-data.nl, farm-europe.eu. 365farmnet.com is a software developing company, with its headquarter in Berlin, Germany. Smart-akis.com is based in Brussels, Belgium; join-data.nl in Wageningen, Netherlands. These 3 platforms are offering for farmers a digital solution for the field recording. With their offered products, the farm receives tailored notifications (e.g. reminders about veterinarian appointment) and suggestions facilitating the decision making (e.g. which fertilizer is better suited in respect considering the upcoming weather forecasts), regarding their individual farm. The platforms are very sophisticated and offering very rich assistance, depending from the farmers willingness of information provision. There is no evidence yet to be found, due to the lack of maturity and it would need counterpart studies of participating farms/non-participating farms, but indeed they seemingly help to reduce the overall complexity of the farm by their digital field recording. A deeper evaluation especially of 365farmnet.com is following at the chapter 2.3.1 “Case Studies”.

Farm-europe.eu is following a different approach. It sets itself as mission to stimulate thinking on rural economies in the EU. It focuses directly on policy areas, that impacts on rural businesses with a strong emphasis on agriculture, food, food standards, growth, trade, resilience, food chains, environment and energy.

It is an independent and engaged voice, which contributes to the overall debate with research, publications and events. It consists of a wide range of multicultural partners, with different backgrounds of expertise, willingly to increase the publicity of their views. It is therefore not offering any digital solutions in the commercially field such as previously mentioned platforms, but independent consultancy addressing the rural farms in the EU. Farmers have the availability to gain insights stemming from engaged individuals, launching a platform to stimulate thinking on the common agricultural policy without primarily commercial interest.

The usage of these multi-sided platforms is crucial for the transition of the European agriculture to meet economic, environmental and upcoming climate challenges, as well responding to the imperatives of food safety. The interface and usability are very sophisticated, but nonetheless remains the lack of participation of most farmers. If more farmers, independent from their farmyards size, would join any of these platforms, then the overall value of the collected data would increase (Stolwijk, Punter, 2018) and coming a step closer, helping the transition of bringing farming to the next level. Even if alone the perspectives are very enthusiastic and seem to create positive externalities, the key statement remains: without farmers, no data.

Some of the aspects contributing to the overall resistance are the lack of transparency, clarity around data ownership issues and similar, portability, privacy, trust and liability in the commercial relationships. The biggest one is representing the lack of trust in between the data contributors (which are clearly the farmers) and those parties who collect, aggregate and share their data (Wiseman et al., 2019).

If smart farming is going to realize its potential, then the broader legal and regulatory issues have probably to be included. Because for now, speaking in particular about the complex data licenses which are presented to famers on a kind of “take-it-or-leave-it” basis, it causes mixed feelings within the addressed farmers understandably. If the data wants to be shared, it is essential to verify terms and conditions are transparent and understandably to all the participants. (Hermans et al., 2019, Fieldsend et al., 2019)

Therefore, I will suggest in chapter 3 within this thesis strategic approaches for pushing participation of European Farmers to enter any Data-Sharing Platform, from the perspective of the generic platform operator, where they should focus their resources and capabilities in order to achieve effective results in the long-run.

2.3 Case Studies

2.3.1 Pilot Projects in Data Analytics of Farms - Documentation

A field calendar is a chronological record with which the farmer manages and controls the agricultural measures to be carried out for arable farming and cattle management. It forms the basis for the operational settlement of an agricultural enterprise and for various evaluations, comparisons or the cultivation planning of the following years. The measures managed with the field record include, for instance, seeds, fertilizers, veterinary appointments for the cattle and other protection measures of relevance. Another function of the field calendar is the documentation of these measures to demonstrate compliance with legal provisions and to ensure the traceability of food. They also simplifies the evaluation, to optimize further proceedings of the farm due to the utilization of the underlying recorded data. In the following I would like to introduce the digital solution of a field calendar, offered by the established agriculture machinery producer *Claas*.

365Farmnet is the data analytical platform provided by the agricultural machinery producer *Claas*, based in Germany. The service provider is performing operations since the year 2013 and aims at offering farmers a digital interface solution in a 1:1 illustration of the agricultural workflow. The overall goal is to track every aspect of the processes and a digital bookkeeping for the obligatory documentation requirements, so that the operating farmer can theoretically fully focus his attention on his field of expertise, which is obviously farming. Additionally, the farmer receives crucial notifications in case of, e.g. legislation violations concerning the commercial farming sector, like fertilizer regulations, or anticipatory warnings which might hinder the overall yield of the farm, like extended heat waves. With this support the farmer receives crucial notifications arriving in time and through this approach the integrating farm is principally allowed to operate more smoothly, and each of the operational steps are traceable. In theory it sounds simple, but the practical realization of this platform is a complicated issue, due to the fundamental requirement of a seamless interoperability of the devices in usage, which are diverged due to farmers different machinery preferences and type of farming.

An animal farmer won´t have the same type of machinery as a wheat farmer does, but nonetheless approaches the platform both types of farmers. *365Farmnet* is overcoming this circumstance as much as possible by cooperating with data/machinery/equipment providers by various actors within the agricultural fields like *Michelin*, *meteoblue*, and *Claas* itself, only to mention a few. There are many different ones, ranging from different fields of expertise and responsibility, to offer the farmer an information rich interface covering all the desired aspects, where the farmer has the possibility to book the applications of the different providers for a defined period, and are visible on the "*365Farmnet"* customized interface, depending as well on the complementary equipment. These applications deliver for example detailed information about the cattle management, seeds, seeds-consulting, planning, route optimization of the tractor, and many different, additionally ones, to let every farmers heart beat higher. The basic option *365Farmnet* is for free usage and the extended version is linked with a cost, but therefore has a very sophisticated offer.

Figure 12 – Dashboard of the customized interface (source: https://demo.365farmnet.com/365FarmNet/dist/index.html#/dashboard)

In Figure 12 we can see a principal Dashboard for the farmers needs, which contains information depending on his own set criteria's. In the picture above these would be a pie-chart providing information about the several crop types (on the left side), a newsfeed about information of relevance for his business (on the right side), a satellite picture about his crops (in the centre), the current prices on the market of his crops (left-bottom side), meteorological services (centre-bottom) and as well an information about the other objects within his business, which would be in this case the cattle management and ground control about nutritional values (right-bottom).

This description is merely precise regarding the generic dashboard of the Demo-Version of *365Farmnet*, available to be tested at the correspondent website *365farmnet.com*. In the real world application, each dashboard differs from another, depending on which parameters and variables the individual user perceives as important. Nonetheless it offers very crucial information about the status quo of the farm and provides almost live updated information of the farm, which helps the farmer to keep an eye on every important aspect of his business. With the help of platforms like these, a very detailed workflow illustration of the farm can be achieved for the futuristic agriculture and reduces the probability of the farmer to lose track of his business, due to the supportive digital architecture.

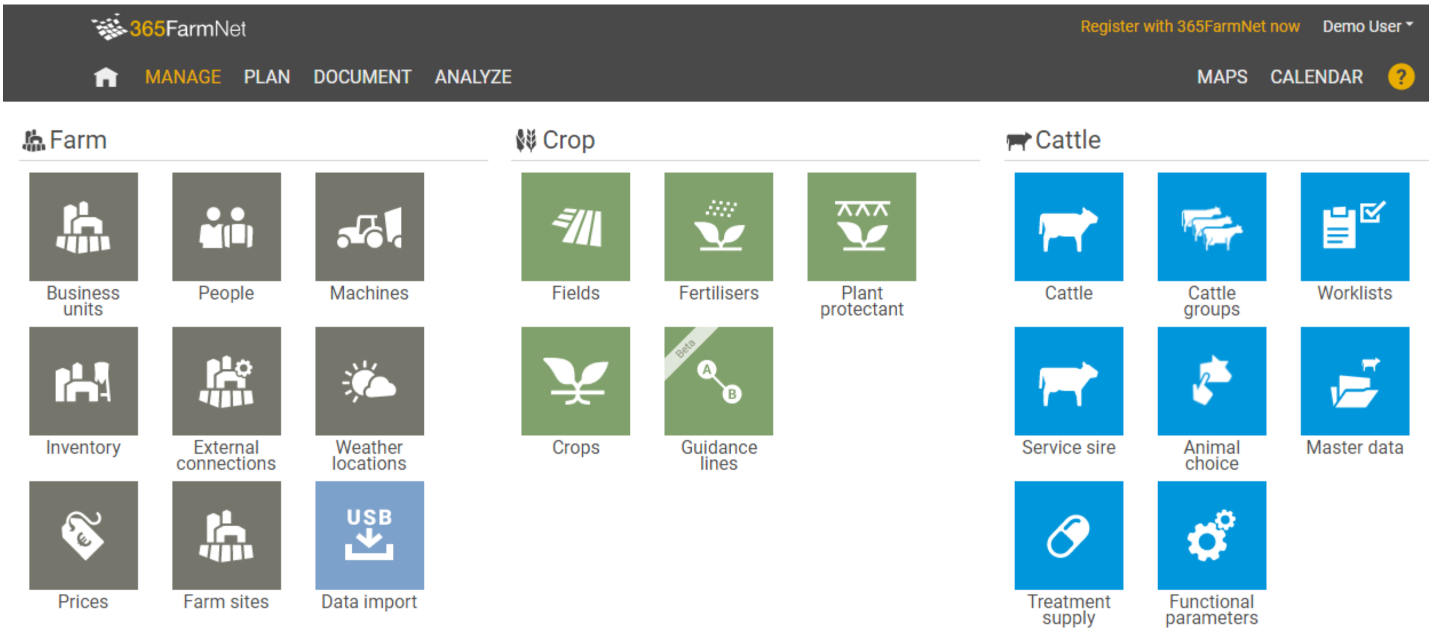
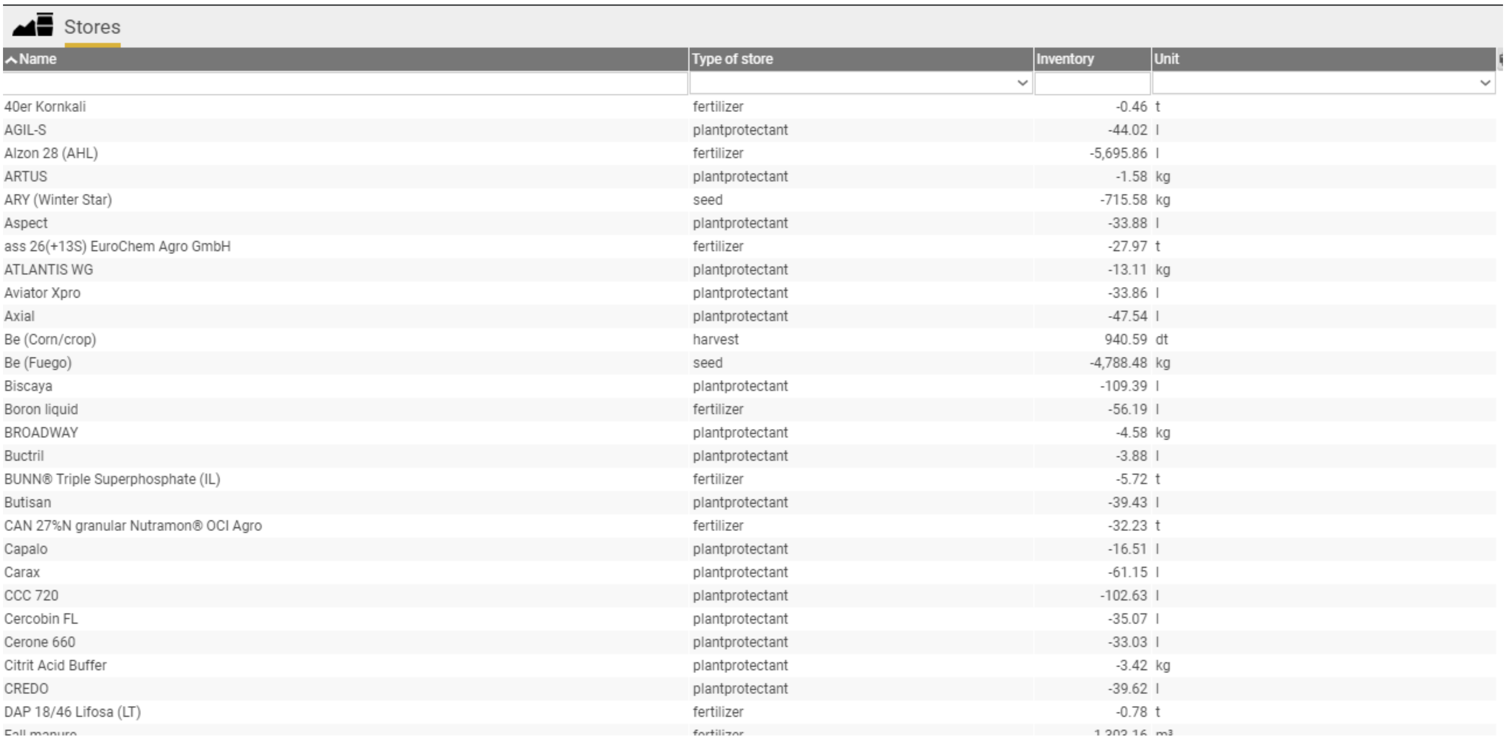


Figure 13 – Macrostructure of the applications the farmer has booked (source: https://demo.365farmnet.com/en/core/index)



Stores

Name	Type of store	Inventory	Unit
40er Kornkali	fertilizer	-0.46	t
AGIL-S	plantprotectant	-44.02	l
Alzon 28 (AHL)	fertilizer	-5,695.86	l
ARTUS	plantprotectant	-1.58	kg
ARY (Winter Star)	seed	-715.58	kg
Aspect	plantprotectant	-33.88	l
ass 26(+13S) EuroChem Agro GmbH	fertilizer	-27.97	t
ATLANTIS WG	plantprotectant	-13.11	kg
Aviator Xpro	plantprotectant	-33.86	l
Axial	plantprotectant	-47.54	l
Be (Corn/crop)	harvest	940.59	dt
Be (Fuego)	seed	-4,788.48	kg
Biscaya	plantprotectant	-109.39	l
Boron liquid	fertilizer	-56.19	l
BROADWAY	plantprotectant	-4.58	kg
Buctril	plantprotectant	-3.88	l
BUNN® Triple Superphosphate (IL)	fertilizer	-5.72	t
Butisan	plantprotectant	-39.43	l
CAN 27%N granular Nutramon® OCI Agro	fertilizer	-32.23	t
Capalo	plantprotectant	-16.51	l
Carax	plantprotectant	-61.15	l
CCC 720	plantprotectant	-102.63	l
Cercobin FL	plantprotectant	-35.07	l
Cerone 660	plantprotectant	-33.03	l
Citrit Acid Buffer	plantprotectant	-3.42	kg
CREDO	plantprotectant	-39.62	l
DAP 18/46 Lifosa (LT)	fertilizer	-0.78	t

Figure 14 – Warehouse stock chapter with detailed information, after opening the Macro-Icon from previous Figure 13 (source: https://demo.365farmnet.com/en/core/stockyard)

This figure gives a detailed perspective, how the digital illustration of the farm might look like. In this case the figure reveals information regarding the warehouse stock.

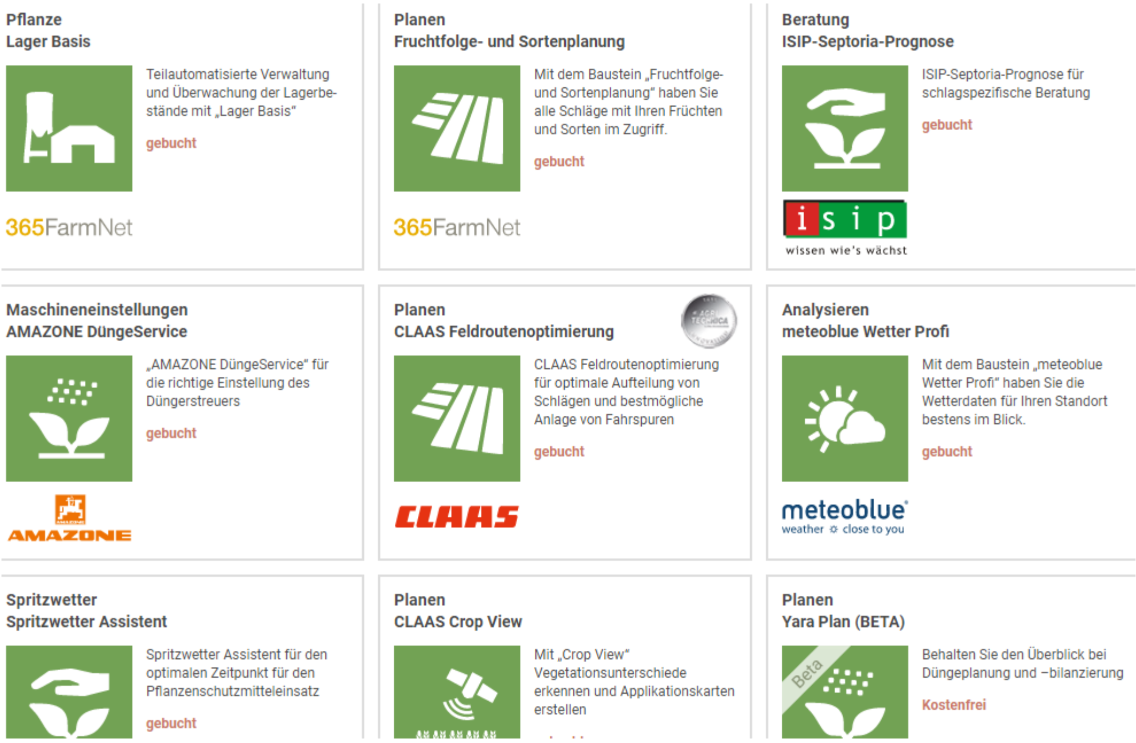


Figure 15 – Applications to be chosen from different providers, depending for usage in need for the type of farming (source: https://demo.365farmnet.com/365FarmNet/dist/index.html#/shop/)

Figure 15 is necessary for a better understanding between the relationship of *365Farmnet* and the external partners. The description to the applications in Figure 15 is in German language, because the English demo version only applications from 2 different providers (*Claas* and *365Farmnet*), therefore the German demo version has been chosen for the figure, to highlight the underlying idea by *365Farmnet*. In this picture we can see applications from different providers, all relevant for delivering detailed information of the field in various aspects. Ranging from prescient planning of the crops, over machinery adjustments up to precise fertilization and seed consultancy, offered by different providers within their field of expertise.

For a better understanding how, the interaction might look like for the futuristic farm, I concentrate on the initially mentioned actors, to picture an integration on the users interface. The *Michelin* application is sending data about the tire pressure, *meteoblue* is providing weather data about the studied land of the farmer covering, e.g., humidity, and *Claas* takes care about the parameters regarding for the machinery in usage. By leveraging the data from these different application providers, the farmer receives on his customized *365Farmnet* interface precious information, how the tire pressure can be adjusted depending on the ground data of the farm, to optimize the touchpoint between machinery and landscape. In this scenario the overall goal of the interactions for the farmer would be, to reduce the tire imprint on the soil, to reduce hardening, which is important to protect the field. This is achieved by adjusting the tractors tire pressure, depending on external environmental factors.

This was a very simplistic example with low impact on the performance of the farm. But in principle all different scenarios could be calculated to optimize the smart agriculture in several manners. Through the collaborative framework of 365Farmnet with external partners, the platform takes care to satisfy as many needs as possible for the farmer with its holistic approach and can guarantee for the user, to be up to date with the latest trends. Therefore, the farmer faces low switching costs and the risk is reduced to be stuck with outpaced technology. Thus additionally the farmer could cancel the membership to any moment, if a further subscription is no longer wished.

Other actors who are providing as digital field record for farmers are: *Farmers Business Network* a since 2014 operating E-Commerce platform, guaranteeing trust and privacy to the subscribed farmers, based in the United States. The platform targets a tighter collaboration between Canadian and US farmers. *JoinData* is the Dutch representative smart farming platform, presenting the similar values as *365Farmnet* and the *Farmers Business Network*. The provider *Netfarming*, based as well in Germany, is trying to sell its machinery with the available digital bookkeeping software, available to its clients. Indeed, these have been only a few of the available smart agriculture providers, and they have similar aims in common, which is simplifying the daily work of the prospective farmer, by illustrating the workflow digitally as much and precise as possible.

This technology and data will continue to enhance farmers efficiency, by further enabling them to monitor each plot of land and in-house m^2 to determine the precise inputs needed for their crops and cattle to thrive. Digital technology is at the forefront of modern agriculture and many farmers using innovative tools to measure and analyse the elements that affect farming, including environmental conditions, seed genetics and the presence of pests. This digital approach is aiming as well to find a relieve within the strict bureaucracy commercial farming requires by legislation. In principle the farmer could therefore mostly concentrate on his daily work and can reach out for support within the legal compliance within his business, due to being updated of the governed requirements. Agriculture is as well due to increasing requirements and duty proofs becoming more and more complex, so a comprehensive agricultural software with which the farmer runs his farm in a manufacturer-independent and cross-company driven approach is from benefit. But is has to be added that a dominant platform will very likely attract most of the farmers and therefore will generate more quantitative feedback for further enhancement of the platforms design, which then vice versa increases the quality of inputs to enable data-driven precision-farming.

2.3.2 Data analytics for crops farming

Farmers still rely heavily on conventional methods to pick the right crop to grow and how to develop the crop in an effective and profitable manner. These conservative manners consist therefore analogic practices, such as of walking in fields, collecting soil samples manually and identifying plant diseases by observing in person the leaves. In addition, understanding the value of technology for acquiring information related to crops in large quantities is crucial for farmers. Integrating big data with the agricultural environment will bring improvements on top of the existing way agriculture is practiced. Many of these steps can be automatized but require the integration of suited digital devices. IoT units are transmitting the data by a wireless network (enabled via suitable channels, depending on the real-world environments characteristics, such as Bluetooth LE, LoraWan, WiFi), to the processing units and the data is going to be analysed.

“Big data analytics analyzes large sized data to discover useful and hidden patterns along with correlations/associations and other beneficial insights. Even though rapid developments in technology have taken place, and traditional agriculture practices are being followed in several countries (especially developing countries). In this regard, big data analytics possesses the capability to positively transform the agricultural domain.” (Shastry, Sanjay, 2020)

The areas in data analytics which is transforming crops farming would be crop forecast, precision farming, historical data analysis, real-time analytics and the generation of high-quality seeds. In a potential futuristic scenario, the interconnected machinery can track the farm and proposes seeds, tailored fertilizers and provides the overall farm with more valuable knowledge, by using principles in AI and predictive data analytics. The data to be collected and relevant for crops analytics would be the average plant growth, soil fertility, fertilizer volume, only to mention a few. Potential synergies across different type of crops within the macroenvironment could as well be identified with the help of Big Data Analysis, and enhance the outcome of corporations of farmers with close geographic locations, without destroying each other’s market.

Due to the huge amount of data inputs from different sources, the digitalized system would be in need of a Big Data analytical approach, in order to help the individual farmer to find potential correlations exactly suited to the farm with its own environmental characteristics and objectives.

The findings and associations of a farm located in place A are not necessarily utilizable by a farm located in place B, where a different climatic environment and soil composition would be existent. For the processing component it is from economical advantage to outsource and take advantage of cloud computing, because it would not be convenient for any individual farmer to purchase a computing system which hits the requirements for these types of operations (Jaimahaprabhu et al., 2019, Shastry, Sanjay, 2020). In the study by A. Jaimahaprabhu and the collegues, “Cloud analytics based farming with predictive analytics using Artificial Intelligence”, a very sophisticated system in an Indian ecosystem have been implemented, with the overall goal to use data analytics in combination with AI to enhance crop productivity. It involves real-time farm monitoring, cloud data analytics and a mobile application. Sensors registered the soil moisture, soil pH-level, light intensity and the nutrient content and a cloud server performed predictive analytics on the sensed data, and additionally data stemming from soil type, landscape, climate, data of the farmers economy and day-to-day market prices of crops. For predicting the suitable crops and complementing fertilizers the system used AI algorithms, and the application included a marketing platform where farmers have been linked with vendors, and the collected data is be used in Big Data Analytics for further improvements, with the aim to increase crop productivity and profit (Jaimahaprabhu et al., 2019). This was a first preliminary example, and others are going to be presented in Chapter 2.5.2 “In field farming”.

The advantages of the utilization of digital technologies in farming would be a higher yield thus more precise and predictive data sets, which are from importance for the next seasons of farming and increase their level of accuracy with each iterative analysis. The predictive analytics facilitates the estimation of a crop within its natural environment and allows to let forecasts happen in case of illness or other extreme events. Events in the past may give insights of futuristic behavioural patterns and reduces therefore the overall operational risk, by generating and capturing data within the agricultural workflow. With the usage of IoT devices and data analytics, it enables the farmer to analyse crop in real-time. The usability and validity of these data sets increase with generated data sets by as many farmers as possible, to feed the algorithm for the Big Data analysis and increase positive externalities. But privacy concerns of data sharing and cyber security issues are probably fostering the scepticism of farmers to integrate this type of technologies into their existing enterprise, as well the perceived complexity, which cause a rejection of adaptation. A solution-oriented suggestion to overcome the reluctance of farmers participation is going to be presented in Chapter 3.

2.3.3 Data analytics for animal welfare

In order to cope with the growing demand for food, new and efficient approaches are needed to improve the agricultures production capacity. Data-driven decisions, processes, and initiatives can enable these industries to increase their potential. A successful integration of information and communication technologies combined with sophisticated approaches to data analytics has the potential to transform some of the world's oldest sectors, including animal-related farming, through all branches. It gives the cattle management a great opportunity to improve productivity and animal welfare. Is the data registered, it allows certain undesirable events to be predicted, monitored and prevented. Consumers often expect changes in focus toward sustainability and an animal-centred approach across the supply chain. Animals interact as well as humans, although it must be remembered that animals are often kept in conditions that do not conform to their natural habitat. To counterpart this development modern technologies offer possibilities for tracking them in various ways, where an animal oriented intervention then can be approached. With the help of technology, their behaviour and habits can be identified, as well as anomalies or improvements can be more easily dealt with to avoid unnecessary pain, as it can help identify slight changes in animal behavior before the clinical signs of illness can be seen. This not only helps increase the potential of production but also increases the safety and social connections within the herd. It is easier for a farmer to control the well-being of a big herd on a handheld computer screen in this technological and data-driven period, rather than by eye observation or manual bookkeeping (Jukan et al., 2019, Taneja et al., 2019, Rieckert et al., 2020).

To enable the monitoring capabilities of farms operations, data collection and exchange, low-cost Raspberry Pi-based programmable systems are suited to meet this demand. From the perspective of data analysis, supervised machine learning would be appropriate to analyse the behaviour of the animals. Machine learning algorithms are suited for the automatic analysis of sensor data, thus large volumes of data increase their performance for the next row of analysis. Supervised machine learning, because it requires low data preparation, and fast decision making is crucial in vivid organisms, especially concerning about animal behaviour. A false decision, how to interact with cattle, could ripple effects and distort overall mass behaviour and create a lot of costs in financial and time related terms. In a supervised machine learning algorithm, therefore, the recorded data is best used to extract timely insights from the data by designing suitable analytical models for thoughtful scenarios that could happen on the farm.

A transmitting network must of course be present to process the data, allowing the data to be exchanged. If this exists, then the fog computing opportunity would be appropriate for this approach. Fog computing can effectively leverage the capabilities of customized cloud computing systems locally on the farm, as it enables storage, communication and application services to be performed at a distributed level. Fog computing allows to execute IoT applications is closer to the point of origin, where the data is generated. A cloud-based approach causes dependency on high-speed internet connectivity and could create latency related issues, which hinder the accuracy of the data analysis, provided by the supervised machine learning algorithm. It would diminish the usefulness of real-time interactions as previously stated and would exclude the integration possibility of small farms in rural areas.

Another design paradigm, which would be from benefit to have, is openness and it be needed to enable communication towards the farms stakeholders. For veterinarians, health organizations, policy-makers and consumers of animal products this is crucial. It would be nice to have to communicate signals, indicating the welfare of the animal. That the animal is free of pain and receiving positive stimulation in their environment, physically and cognitively, if this type of integration is possible to be achieved through the farms internal. This approach is also aligning with the initial concept of the unified welfare, which recognizes direct and indirect links between animal and human well-being. A environmental friendly production system on top of it realizes the connectiveness of the 3 pillars, human, animal and environment. (Jukan et al., 2019). But surely, privacy concerns and cyber security has to be guaranteed as well, because elsewise the farm is sensitive from external events which could ruin the reputation or spread misguided information with little effort by the attacker.

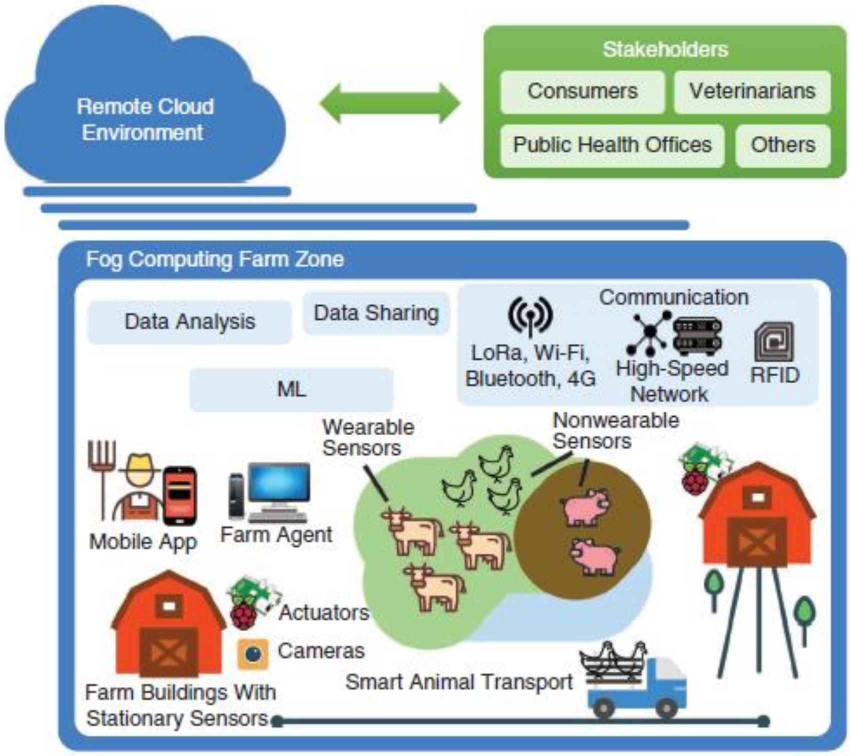


Figure 16 – Model of how animals can be connected and the accordingly data distributed (source: A. Jukan et. al. 2019)

Figure 16 describes a framework of digital technologies, which are needed to digitalize the farm. Notable is the difference that in cases of bigger cattle, just as cows for example, it is worth putting a wearable sensor on them. Sensors for animals are rarely used due to the short life of the animal and the relatively high cost of the sensor. Stakeholders from different interest groups (consumers, veterinarians, public health offices) are mentioned as well in the model, due to the potential integration within the communications network. The sensors are exchanging the data with the help of a suited transportation layer, in order to get analysed and processed. How already mentioned, is supervised learning the optional solution for detecting animal welfare, due to the machine learnings model training to map an input to an output, by previously generated examples of input-output relationship, to access timely a supportive opinion to maintain animal welfare and reduce operational risks of the farm.

For cattle held inside, additional sensors to monitor the interior life of the farm are giving further insights, how to engineer the environment for the animals benefit by increases the quality and accuracy of livestock observation in almost real time.

Environmental sensors like temperature and water quality are essential characteristics that affe ct each animal in a barn directly. Additionally, temperature sensors and other environmental p arameters involving hazardous gas sensors for ventilation control, to measure gas concentrations like CO_2, NH_3 and H_2S. Video cameras and microphones are ideal sensor systems for data generation for monitor the animals location, movements and resting behaviour during sleeping. They are also very good for studying the eating and drinking behaviour at the trough. An analysis of this type of data may classify instances of tail biting or other competitive behaviour. With this insights, interventions of the interior design of the farms can be adjusted to reduce the likelihood of occurrence of these aggressive patterns. These insights increase productivity in the long term by getting insights for improving the farming practices and reduces operational costs, compared to conventional labour practices within animal farms with use of intensive human labour. (Rickert et al., 2019, Taneja et al., 2019)

In this technology-driven era farmers look for assistance from smart solutions to increase profitability in order to manage their farms well. The overall goal for the smart agriculture of tomorrow is to use sensors in various manners in able to detect anomalies of the animals behaviour, record the data to get insights of mechanisms that provoke the likelihood of unwished accidents in order for solution oriented approaches of how to prevent the occurrence for upcoming scenarios the animal will face within the farm. This early alerts towards the overall well being by assisting the farmer also helps increasing the quality and as well productivity, because it helps to identify potential diseases early on. A minimal intervention is better than maximal therapy, considering the animal welfare as well in financial terms. Surely the papers studied within this thesis are all at the beginning of implementing digital technologies into the farm, but the first trials are appearing as promising and further, interesting and more specific case studies are probably going to presented soon by scientists active within this field of research.

2.3.4 Machinery

Agrobots is the generic name for robots and machinery which are fully independent operating on farming land to carry out processes which would require otherwise a lot of human labour. Fully automated processes of machines in the agricultural sector are very appealing, due to their low variable cost while operating and the big amount of flexibility. A machine can theoretically be switched on and off at any time, in comparison to human labour. Streamlining and automating processes that deal with growing plants and crops must be implemented within the food supply chain in order to achieve the overall goal for a sustainable food production for the world population by the year 2050. A machine could in principle work 24/7, which is an attractive feature especially during the high times of the harvesting period.

It exists a lot of interest in fully automated agriculture, also due to the increasing difficulty of finding labour forces which are willing to work and execute hard work in the agricultural sector. The Harper Adams University, based in the United Kingdom, is complementing a research study, called "Hands Free Hectare", which aims as the name says, to establish an agriculture, which is totally independent from direct human labour input. (harper-adams.ac.uk/research/project/196/hands-free-hectare). Regarding the latest achievements, the research group was able to extend their efforts up to 35 hectares, which correspond to an area of 3.500.000 m². For a more vivid description: 3.500.000 m² correspond to about 490 soccer fields (one soccer field has an area of around 7140 m²). This is a very broad space for farming, but it must be added that no information was provided about the productivity of the occupied field itself. But nonetheless the occupied area speaks for itself, in the sense of the promising expectations of the overall project. *"A successful outcome will disprove the currently accepted opinion that agricultural autonomy on the field scale is unachievable, and as a consortium we have confidence in the capability of these low cost systems to radically change the approach to field agriculture in the UK.",* quoting the statement provided on the Universities website.

The type of use cases, in which autonomous machinery is explored, are very various and creative. One research group dedicated their work and effort to build a machine, that has built an electronic nose in order to sense, if a peach is mature or not, with the help of chemical sensors based on metal oxide materials (Voss, Stevan, Ayub, 2019).

An Agrobot like this simplifies the time intense working step, which is additionally depended on the long year subjective experience of the farmer. Another research group presented the opportunity of a robot, which was designed in order to detect insects with the embedded system and kill the larva's of the insect, once detected with an algorithm. This approach substitutes the usage of pesticides and offers a more environmental friendly farming approach (Obasekore, Fanni, Ahmed, 2019).

As well in the commercial agricultural sector are many firms active in producing Agrobots for various employment cases. I´ll only mention a few, to give insights to spark the imagination, what kind of automatized applications are for now available for the future of agriculture. The US based firm *"NVIDIA*", which is mostly known as producer for Graphics Processing Units, is as well active in the field of automated agriculture machinery. It published its efforts about developing a drone, which is flying over the fields of crops for taking pictures, to detect nutrition stealing weeds early in time. The pictures are evaluated with an AI in order to inform the farmer early enough in time, to avoid a bigger spread of the weed, which would then force the usage of pesticides. The Dutch firm "*Florensis"* is selling tulips and integrated a machine within their streamline, developed by the "ISO Group", also a Dutch based firm. The machinery is planting the seeds automatically, and as well cutting the tulips once the plants are grown and ready to harvest. This is a very sensitive approach and requires fine motoric skills by the robot, elsewise the machinery would destroy the surrounding tulips while cutting one flower.

Another Dutch based firm called "Cerescon" is offering a harvesting machine specialized for asparagus. The difficulty by harvesting asparagus is that it is a selective approach. The machine must distinguish with the help of sensors, if the asparagus is ready to be harvested or not. Because in the case if the crop is pulled out to early out of the ground, it is destroyed. It is either edible either can it be planted back. The utilization of this type of machinery saves time, exhausting labour and money due to the low error rate of detecting, if the asparagus is ready or not.

Despite of the already existing machinery, which are commercially available, many patents have been already registered within the year 2019. When using the keywords "automatization", "machinery", "agriculture", "smart agriculture", several interesting patents have been found.

To mention a few: “Robotic injection system for domestic herd animals” injects vaccines, reproductive hormones, and other veterinarian liquids to domestic herd animals. The robotic injection system includes a cooling-unit for storage of the liquid materials; a series of automatic gates to control the movement of herd animals; an RFID and camera ID reading system utilized for tracking identification numbers and medical history; a robotic arm to position and apply force in the injection process and an injection mechanism for delivering injections to the cattle. The “Inertial collision detection method for outdoor robots” is a fully self-manoeuvring weeding robot, composed out of a motorized cutting subsystem, which cuts automatically weed when detected by the controlling units. If they will be produced and further developed, is yet uncertain, but the registration has taken place regarding the responsible bodies.

The future of smart agriculture, in a fully automatized sense, are looking very promising by studying the current available technologies and the undertaken effort within the private sector by producers of various fields. As well the research effort published by the Harper Adams University and their “Hands Free Hectare” project is very astonishing. Until fully automatic agricultural machinery will be commercially available in a big scale and universally applicable to environments, will probably still pass a lot of time. It has to be added, if a robot functions perfectly in environment A, it would be thinkable that the robot will face difficulties in environment B, due to for example differences in the state of humidity of the soil, unless the robot received enough training data. But the beauty within this approach relies, that a recorded data set can be utilized for robots in different domains. Meaning, that the collection of environmental data in every manner of an area can in theory be collected, processed, and used for the algorithms of the robotics software program. But for this smoothly interoperability to happen, it would require standards and openness of the data. And for now, the introduced robotics are very effortful in one domain, but not in applicable in a different one. It is technological very sophisticated to design a robot which has an electronic nose for peaches, but this feature makes him useless in the case of recognizing the state of maturity of apples. Therefore, it will pass still some time until the universal applicable robot, suited for multiple kind of challenges within one domain, will be available for commercial farming. And until the technology mature enough, there are still questions remaining open which came upon my mind while researching.

It also must be thought about the set of complex interactions, in the sense that robots can basically transfer diseases collected by animals or plants, and therefore potentially contaminate other animals or plants even faster than without the usage of any robot. As well should be thought about the fact, that the agriculture industry relies heavily on transactional business operations and in case of an error of the robot, who´s insurance company is going to pay for the damage? These are some questions which came upon my mind, with which I want to demonstrate, that the usage of robots in agriculture is not completely risk free. Surely the outlooks are promising and interesting, but before implementing these automatized solutions within the global food supply chain, it should also be thought about the emergency architecture in the case of defaults.

2.4 Blockchain in Agriculture

2.4.1 Traceability, Permissioned/Permissionless & Food Security

A blockchain is a subset of the distributed ledger technology, which means that a shared ledger is stored locally by all the participants of the network, instead of storing it on a centralized server. The blockchain stores all the information in logical blocks which are then chained together. Since these blocks are cryptographically connected, a change of one information in an existing block leads to a change in all of the following blocks, which makes all undertaken operations tamper proof and visible for all participants, since it is storing information chronological of all transactions. The blockchain technology is in the consumer cycles not yet fully arrived, nonetheless it offers appealing solutions for the set of problems the agricultural sector. The food producer and the other subsequently businesses which are handling the agricultural goods can easily claim false statements on the dispenses of the end consumer. Products can effortlessly be presented as ecological sustainably or animal-friendly in order to gain higher profits, but it does not mean necessarily that the products history is at it is claimed in the retail store.

Food traceability within their supply chains has become very important in a world in which economies are increasingly competitive, heterogeneous and diverse, and in which consumers demand a high level of quality. Due to technological complexity combined with a lack of cooperation, the food supply chain consists of many actors, which have individual interests and are reluctant to share information with each other. If they would reveal crucial information about their operations, they might set out their individual business a risk of forward or backwards integration; a potential threat stemming from the other actors in the same food supply chain.
Thanks to innovative Software Engineers, the blockchain is overcoming the obstacles and advocates improving traceability by introducing an additional, digital layer of trust.

“Standardization of traceability processes and interfaces, having a joint platform and independent governance were found to be key boundary conditions before blockchain can be used. Our findings imply that supply chain systems have first to be modified and organizational measures need to be taken to fulfil the boundary conditions, before blockchain can be used successfully” (Behnke, Janssen, 2020)

The genuineness of the underlying product can be guaranteed, which is a crucial feature in times where false claims can be made with little effort on the cost of others. For the retailer, and as well for the other actors between the products point of origin up to the taller in the supermarket, it is easy and appealing to claim a product as sustainable and ecological. Consumers are more interested to know if the products of desire have passed through a sustainable supply chain, and are able to control this with the underlying digital technology of the blockchain.

The customer has access to this information within seconds by scanning with the Smartphone a QR or Barcode for example, which function as information gate between product and access to the stored data within the blockchain. This layer of trust mirrors the sustainability and principles of the values the customer is representing, and therefore could become soon a necessary feature for any producer of food, in a globalised interactive world of market participants.

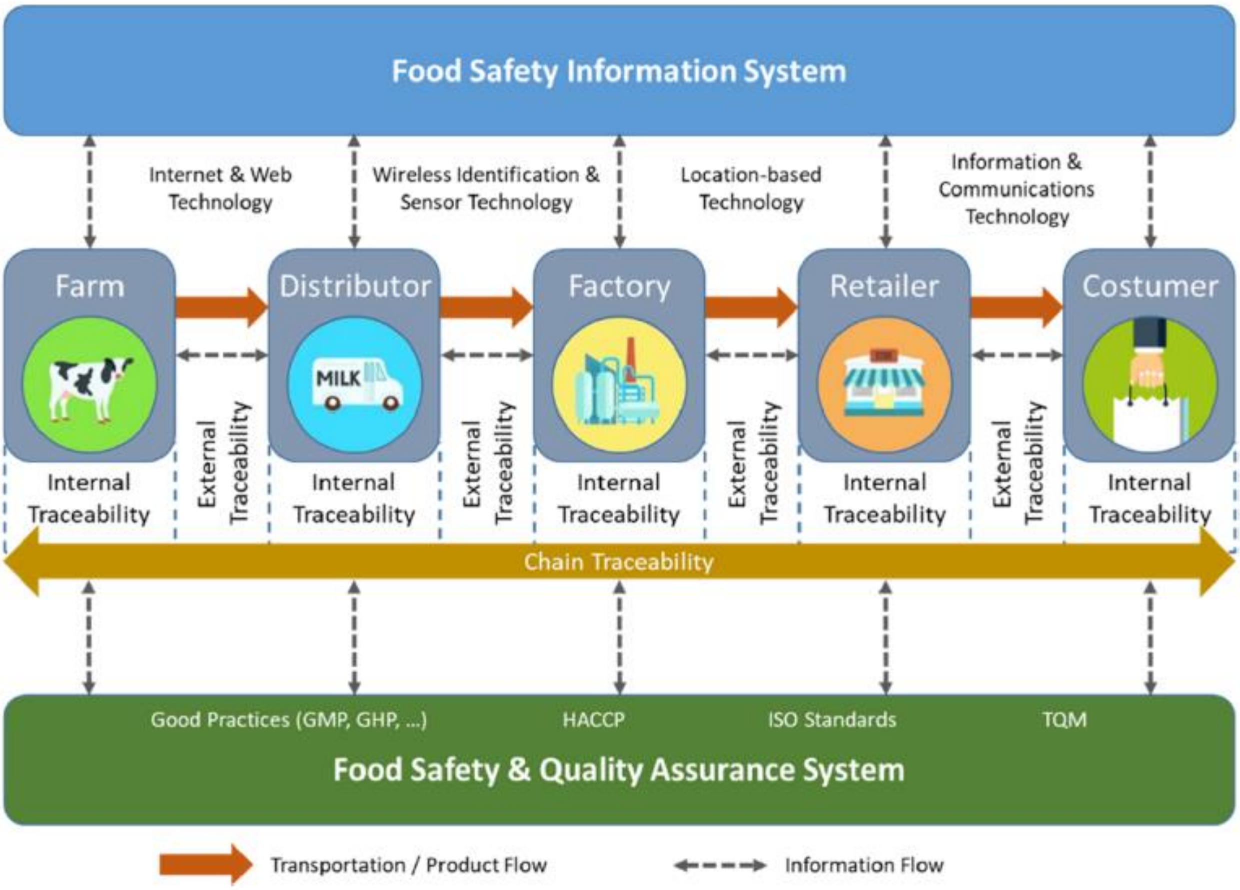


Figure 17 – Conceptual model of a traceable food supply system (source: K. Behnke, M.F.W.H.A. Janssen, 2020)

Figure 17 describes a model of the information traceability in the example of milk, from the point of origin up until to the end user, consuming the milk-based product. With the help of the blockchain the consumer could retrieve all information which has been previously recorded and stored in the blockchain through suited sensors system. Internal traceability covers the internal process of the individual food processing actor, whereas external traceability describes the relationship between two actors of the overall supply chain. With the blockchain technology the requester has access to tamper proof information, depending on the sensor's resolution, which records the to-be-stored information, which is from interest for every actor within the food supply chain. Whatever is written into the blockchain will always be stored within it, because it is storing the information chronologically. To determine which information will be written into new blocks of the blockchain, all actors need to agree on shared rules, the so-called consensus mechanism. Any party with the right to read the information can audit all transactions, since there is a transaction history under which the assets lifetimes can be tracked. Consequently, this leads to a high degree of provenance since all transaction records are visible to everybody with access to the data. Through this sophisticated technology an additional layer of trust is introduced, and the overall outcome is an enhanced level of transparency (Behnke, Janssen, 2020, Jahanbin, Wingreen, Sharma, 2019)

Different entities use a blockchain for different purposes in different environments, and as the blockchain has risen, two dominant types of blockchains have emerged, the so called permissonless and permissioned blockchain. The difference between these two different options is going to be discussed in the following.

A permissionless blockchain is most simplistic described as one, that enables the entries to be shared, updated, owned and controlled by all participants. Principally literally any entity can use a processing devise to join the network. The permissionless network has the benefit of truly decentralization and openness, which increases the trustworthiness and transparency of the network. On the other side it faces constraints in large-scale usage, the so-called bottlenecks. Transactions can need more time as assumed to get validated by the blockchain, depending on the design decisions of the previous set consensus validation mechanism. If a node owner suggests a different consensus validation mechanism of the network for multiple reasons, it might result in a slowly progressing act, because every participating node owner must agree and integrate the changes for the network of nodes to continue - same counts for introductions of software engineering specific changes over the previous defined ones. Even if a change might be technological speaking more appealing does not promise the introduction of the update.

All the participating nodes in the network would have to re-write the software for further participation, which enhances the likelihood of conflicts to occur. In the other hand, a permissioned blockchain has restrictions within its participants and validation mechanisms. The inherent validation mechanism defines the roles of each node as well distinguishes, which participant can access and write information on the blockchain, or either approve/disprove credibility of new members. Due to this cherry-picking definition of access and control authorizations, a permissioned blockchain regards as only partially decentralized, unlike as the permissionless one. Due to the selectivity of instructions and rules for the networks participants roles, a permissioned blockchain reaches bigger efficiency to fulfil the desires of requesting enterprises and secures privacy related concerns (maybe an actor does not prefer full disclosure of information for the other ones, or only selectively full disclosure). On the other side, this privilege might undermine credibility of the overall network, due to the possibility of single entities to manipulate/override the state of the ledger without the need of permission by the other participating nodes. In one sentence: it is a very undemocratic type of blockchain. (Liu, Wu, Xu, 2019).

Due to the fact of full disclosure and transparency the integration of a permissionless blockchain makes more sense over a permissioned one. In the case of a permissioned one, an actor could principally withdraw crucial information and present himself therefore as an ecological and responsible entity. If the blockchain technology at all is going to cause big changes at a consumer behavioural level remains open, but first trials are appearing promising. The French retailer *"Carrefour SA"* could register notifiable changes since the integration of the blockchain technology. Single products, such as pomelos, gained notifiable increase in sales, compared with the blockchain-free pomelo of the previous year.

It is an interesting outcome, since the introduction of the technology in combination with pomelos is changing purchasing behaviour. No specific study regarding consumer behaviour and pomelos could have been found, but pomelos are widely known still as quite exotic types of citrus fruits, and therefore not on the regular diet of the average consumer. The introduction of the blockchain technology made seemingly the difference in the purchasing behaviour within only 1 year, which a remarkable observable change. Also other products, offered with blockchain integrity, hit the right stimulus of the consumers nerve.

In the case of *"Carrefour SA"* consumers preferred the blockchain-chicken over the non-variant one, which is also a remarkable example of the positive acceptance of the technology's integration. The integration of the blockchain technology increases obviously the reputation of a product and the advantages within the overall agricultural sector are multiple, which are going further to be discussed in chapter 2.4.2 "Necessity of Blockchain for enabling a Smart Agriculture". Due to the lack of maturity the future outcome is uncertain, but the first adaptation trials are looking promising and in favour of the end consumer.

The blockchain technology also holds the potential to shape the food management system, thus increase the overall state of the food security within the food supply chain of an economy. With the trustworthy information provided by the actors and accessible due to the blockchain, the food retailer, or any other actor in between the food supply chain, can verify if the product is at its point of location as it claims to be. A blockchain based information system, integrated with IoT, removes the need for a trusted centralized entity by introducing a new approach in increasing trust among participating members. Through this tracking and traceability oriented implementation, the management of the whole agricultural food supply chain can be observed, adjusted and optimized. For a better visualization of previous statement, I created following illustration:

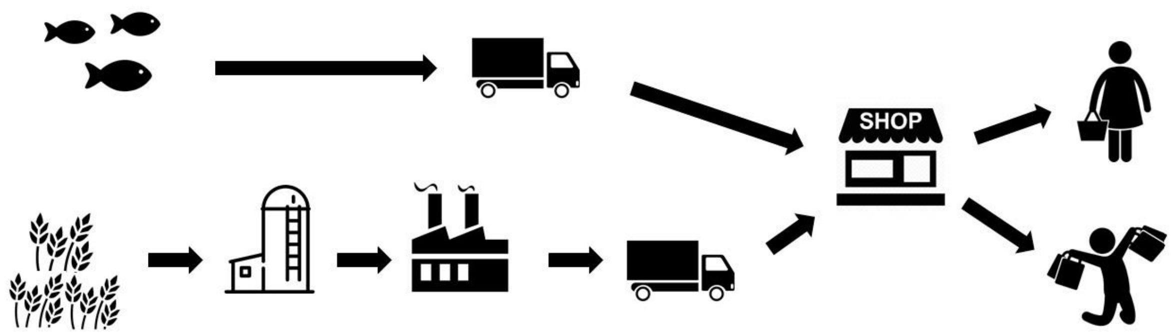


Figure 18 – Simplistic model of the food supply chain

The graphic is very simplistic and describes roughly the steps in logical order, how food products are passing different stages until they reach the end consumer. Fishes are best consumed if they are fresh and should enter the retail store as quick as possible. Whereas grain has to be processed before it can be consumed in any form, therefore it surpasses previously a storage and manufacturing phase, before it enters the retail store. If IoT devices and sensors are implemented at every step within the overall food supply chain, the individual steps can be registered and then stored within the blockchain. Depending on the quality, quantity and diversity of the sensors, many data is going to be generated which are then afterwards, after storage in the blockchain, are available for the participating nodes within the network. With increasing recording of the data, created by each actor within the food supply chain, more data will be available for further analysation.

These data sets could be used in analytical algorithms, such as Big Data Analytics and AI, and the liability of the data is guaranteed by the blockchain technology. With increasing production and analysis of the data, optimization processes are more applicable, in the sense that in theory exactly the quantity of food products are going to be produced and delivered, as later being sold in the retail store.

Or vice versa, the retail store and the other actors can adjust faster to unexpected changes than without an observing layer. The retailer is offered by the blockchain a trustworthy layer, to control if his order is going to arrive as expected by the ability of continues communication. If less fish is available in the sea, the retailer can re-arrange his local offer to the market timely by offering a substitutive product for example. With increasing available data, the algorithms are able to improve their prediction quality of real-world scenarios in order to reduce the food waste, which increases the overall food security of a system. If everything would be optimized, the prospective customer would be able to pick up the food in the retail store, which got placed just a couple of minutes before the customer made his decision to purchase it. This is of course a very utopic example, but would be in theory executable, with enough data and a smoothly, digitalized interacting food supply chain. The overall point I would like to make is: With increasing iterations of data creation and analysis, the quality of the predictive data sets are going to increase in order to improve the accuracy of the algorithms, in favour of the end consumers to enhance the food security in the environment. It has to be added, that the blockchain technology is still a very young technology. Until maturity and adaptation in a bigger scale by more actors, it will pass some time.

2.4.2 Necessity of blockchain for enabling a smart agriculture

The blockchain technology will be probable one of the crucial technological means for enabling the transition from a classical into a smart agriculture. One of the main concerns of farmers about the digitalization is their privacy and security concerns (Wiseman et al., 2019). Assuming an interconnectivity of all processes within a farm, enabled through a sophisticated IoT network, also bears the risk of exposing the farm to different forms of cyber-attacks. External entities could have in principle the possibility to dysregulate the processes and manipulate the digitalized farm in multiple ways. Privacy, authentication, confidentiality, availability and integrity attacks performed by externals, with the aim to harm the farm, are thinkable (Ferrag et al., 2020). The exposure to these potential threats is definitely against the farmers, and the farms stakeholders, interest. But a securitization with the blockchain protocol between the communicating nodes within a farm, the likelihood of success of these cyber threats is going to be reduced.

The blockchain, how stated in the previous subchapter, is a continuously growing list of records, called blocks, which are linked and secured using cryptography. As it is a decentralized system, it is maintained by multiple participants on the network who are responsible for securing the data by being a immutable system and reaching network consensus. A blockchain system runs without the concept of human trust, meaning that any code or functions are guaranteed to execute as programmed, as long the network is online. The networks are built in such a way that it assumes any individual node could principally attack the overall system at any time. Consensus protocols ensure that, even if an attack of one node happens, the network completes its functions as intended regardless of cheating attempts or human interventions. The blockchain allows to store data of any kind and secures it by using cryptographic properties, such as digital signatures and hashing algorithms. As soon data, potentially provided by an IoT device, enters a block in the blockchain, it cannot be tampered due to the immutability of the protocol. Every record that has been written on the blockchain is secured by a unique cryptographic key, which is virtually unhackable.

When a new record is written on a new block within the same chain, everything from the previous record, including its content and its key, is put into a formula to generate the key of the second record, which creates dependency between these 2 blocks. When a third content is created, the contents and the keys of the two previous records are put into a formula to establish the third key, which creates again a dependency and the overall process is repeated until the chain of blocks is full and no further block can be added. Every record created makes it more complex to alter the history and if anyone would to try to manipulate a blockchain database, network consensus would recognize the attempt and shut down the attack, because the majority of the participating nodes need to reach consensus before any decision is made. So if an attack wants to succeed, it needs to gain control over the majority of participating nodes, which is with conventional processing units by hackers very difficult to achieve, due to the decentralized distribution of the participating nodes within a blockchain network (Ferrag et al., 2020, Behnke, Janssen, 2020, Jahanbin, Wingreen, Sharma, 2019).

With the help and idea of the blockchain protocol, the farmer can secure the digital communication between the analogue-digital interfaces and IoT devices of the farm, to reduce the likelihood of being successfully exposed to a cyber-security threat of various kinds. It should increase the trust into the digitalization of his underlying farm and overall, it is a necessary step before any discussion of data sharing outside of the farm can take place. The blockchain technology is guaranteeing with its underlying protocol the tamper proof genuity of the recorded data. If the previously recorded data is manipulated afterwards externally for any kind of reason, it won´t serve any good for further data analysis, due to the lack of the data integrity. But if the data is recorded and secured by the blockchain protocol, the trustworthiness and accuracy of the data is provided for any kind of further utilization, and on top taking care of security and privacy related issues of the farmer, because it empowers to true ownership of data, which increases the control over the intangible digital asset, the data. It reduces fraud, distortion and enhances safety, security and quality of the data.

Nonetheless, even the most innovative and high-level technologies are impractical, if they are not properly being adopted by their users, despite the potentials. There is not yet enough evidence available which states any kind of superiority between different blockchain systems or rates of adoption within the agricultural sector. But the idea is appealing and promising for an innovative approach.

2.5 Precision farming

Precision agriculture is a method, in which farmers are given the possibility to optimize inputs such as water and fertilizers, to enhance productivity, quality and yield. It also involves minimizing pests and diseases, through targeted applications of each cultivated field in an appropriate way, because they differ inherently by various factors. May it be the soil compositional differentiation or the sun is shining with a different angle on each field - there are varying ecological factors to be considered across the sectors and parcels, to optimize the crop productivity or to prevent the outburst of unwishful outcomes, like the continuous spread of diseases. It is a farming management concept, based on observing and responding to in variations enabled through information technology, which first step entails to evaluate all available information to give a better understanding of the variabilities causes of the farm, which enables the opportunity for a better management. In the following three precision farming concepts are going to be presented: pattern recognition in leaves, in field farming and in greenhouse farming.

2.5.1 Pattern recognition in leaves

Plant disease diagnosis, by human observation, requires a very high level of expertise. Due to the large variety of cultivated plants and the existing, different plant-specific problems, also experienced farmers and/or plant pathologists fail sometimes to diagnose the specific disease, which then may lead to wrong judgements and treatments. “An image that we see with our eyes is analogous in nature to the image captured via digital camera. By definition, an image is nothing but a matrix of different intensity levels.” (Tunio et al., 2019). This statement highlights the employment opportunity for computational systems, as an assistance for agronomists for the detection and diagnosis of plant diseases. The literature suggests the usage of convolutional neural networks, a type of neural networks within the realm of deep learning, due to their characteristic favouring the search of particular patterns by the technical operation of convolution.

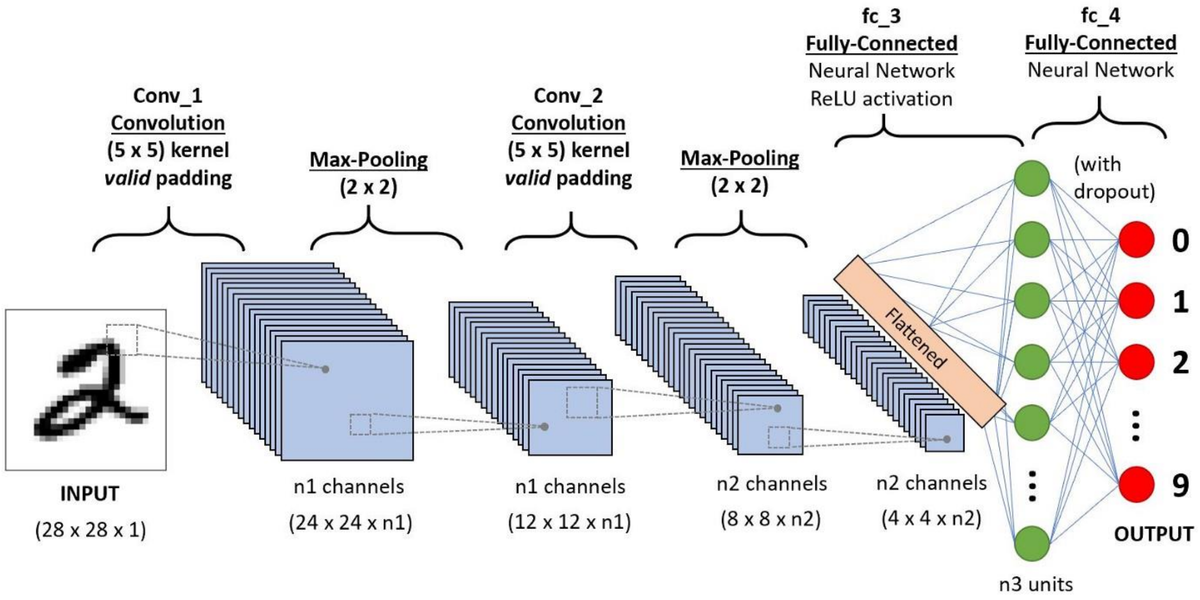


Figure 19 – The principle of convolutional neural network for automated image processing (source:towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53)

Figure 19 is describing the conceptual model of a convolutional neural network (short CNN). It consists of many componential layers, which are very difficult to describe properly without deeper computer science background in a few sentences. Nonetheless, one of the key features of deep learning algorithms is that, a CNN can learn to filter characteristics by its own, which is very sophisticated compared to primitive hand-engineered method filters. This approach can be an advantage for the recognition and classification of plant diseases, because every leaf, even when stemming from the same plant, is biologically differently shaped. Surely the neural network still needs to be trained with the help of botanists for each specific plant type before it can recognize irregularities (Baio et al., 2019). In the following a few examples will be introduced, where deep learning algorithms can help to facilitate the decision making process.

The leaf detection algorithm allows an early, solution-oriented intervention in order to maintain the plants health. Once the infected leaves are recognized by classification with a deep learning algorithm, it also allow curing the diseases through a precisely targeted amount of pesticides. Surely, different types of plant diseases require different specific pesticides and the purpose of precision farming architecture is, to receive in real time the right data to increase crops productivity and maintain the quality.

Figure 20 – Leaves from different plant types and diseases (source: N. Tunio et. al., 2019)

Figure 20 demonstrates different leaves, stemming from different plant types. Obviously, the banana leaf is easily to be distinguished from the bean leaf, but shares some familiar characteristics with the guava leaf in its shape. The classification algorithm overcomes this problem by considering also the skeletons inside the leaf, by applying different filter methods. On the right side of figure 20, all leaves are stemming actually from different plant types, but due to the disease some characteristics of the leaf becomes different and this may get misinterpreted by the classification algorithm. Without careful training previously, this might give wrong suggestions for treatment, or also not recognize the existence of any underlying illness. The algorithm might recognize a leaf stemming, from a plant type A, as healthy, whereas in reality it is an infected leaf from plant type Y.

Such undetected error causes a wider spread of the disease and would require a broader usage of pesticides or even cause the crop to die. This was just an example to highlight the potential error, but indeed the algorithms have a very high accuracy rate between 80 % - 95 % for detecting plant types and underlying diseases accordingly, according to the papers. Each classification trial increases the database and the accuracy.

Figure 21 – Tomato leaf disease (source: K. P. Ferentinos, 2019)

Figure 21 presents four tomato leaf diseases, which by simple observation could lead to the conclusion these four diseases are all the same, but in different metamorphotic stages of the underlying pathology. Without the help of a trained plant pathologist who has a lot of experience, it is unlikely that the deep learning algorithm will be able to distinguish accordingly (Baio et al., 2019). Therefore a lot of time and close operations from experts are needed, to provide a very rich database, in order to train the neural networks as good as possible. Another important factor is – the studies have been done in controllable laboratory conditions. When the algorithms are used in future to detect in open field, they will face a different environment than in the laboratory one (e.g. UV components of the picture recording), which could lead to wrong classifications. In field conditions, images will contain several volatile factors, such lamination, blurry picture qualities or noise in the background. Until now, most databases are dealing with leaf diseases, and not diseases stemming from the plant stem and as already mentioned, the differences between disease species in the same class are very subtle (Tunio et al., 2019, Dawei et al., 2019, Mosin et al., 2019, Ferentinos, 2018). The usage of classification algorithms for the pattern recognition of plant diseases will definitively need more trainings and a richer database for increasing the accuracy. Nonetheless the outcomes are very promising, which will lead in the smart agriculture a timely recognition of plant diseases, which will reduce the likelihood of the spread and entail a precise usage of pesticides.

2.5.2 In Field Farming

Arable agricultural farming is the production of crop yields on cultivated fields. The traditional way of farming is the principle of the tillage system, where the same field is cultivated year after year after year and so on. This reduces managerial complexity, but also has its downside effects. If every variable of the environment, including soil and climate, would remain constant over all the years, this simplistic approach would not present any problem at all. But the reality looks different: continued cultivation of the same field with the same specific crop diminishes the nutrition content of the soil, which then causes increasing amounts of fertilizers for every subsequent cultivation, because the soil is not given enough time to recover itself. Additionally, the climate is undeniable changing, and this represents a threat for global food security, because it changes the external variables. Unusual extended heat waves or the lack of rainfall is causing the crops to die. The climate therefore possesses the threat of unexpected (yet uncalculatable) changes of the external, natural resources. To reduce the harmfulness of these two factors, the repetitive practice of the tillage system and climatic changes, the introduction of a data-driven supportive decision layer would be from benefit, in order to increase the farmers effectiveness of sustainable decision making.

“Plant breeding and agronomy are labor-intensive sciences, and the success of these disciplines is critical to meet planetary challenges of food and water security for the world’s growing population. Recent gains in sensor technology, remote sensing, robotics and autonomy, big data analytics, and genomics are being adopted by agricultural scientists for high-throughput phenotyping, precision agriculture, and crop-scouting platforms. These technological gains are ushering in an era of digital agriculture that should greatly enhance the capacity of plant breeders and agronomists.” (Northrup et al., 2019).

More data is available in agriculture than in any other industry because of the potential infinite variables that influence the prospective crop. The underlying technology to analyse the huge amount of these data is obviously Big Data Analytics, enabled through IoT (Internet of Things), by sending the data through an underlying transmitting network. IoT refers to devices or things, that are embedded with a sensor so they can measure and transmit data via a network. Essentially, IoT means these physical devices can send and receive information via the Internet.

On farms, IoT allows devices across a farm to measure all kinds of data remotely and provide this information to the farmer in real time. Devices can literally mean anything from pumps sheds and tractors to weather stations. The architecture of data-driven farming is therefore using sensors, algorithms and digital networks to guide decision making, to put data together which goes beyond the all-important farmers experience, analysed with the help of Big Data analytics. This digital technology, IoT, is driving the essential change in agriculture and the variability is almost limitless. IoT devices can gather information like soil moisture, chemical applications, and livestock health, as well as monitor fences, vehicles and the current weather. Data generated by the IoT allows to track farm operations and make better informed decisions to improve farm productivity in yield, in order to respond more quickly to their conditions, saving time and money. Whether knowing when to check on water supply to prevent a trough, or how much and which specific fertilizer to apply for a crop.

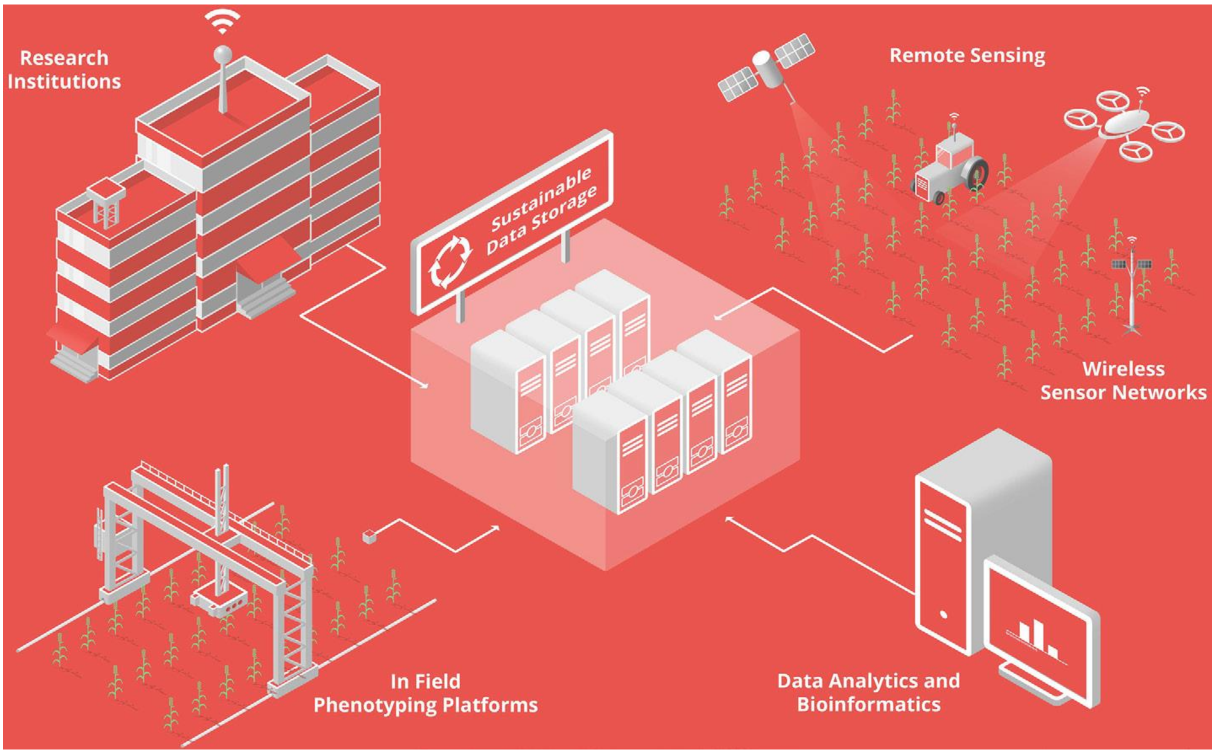


Figure 22 – Conceptual model of the interaction between IoT, data analytics and research activity (source: D. Northrup et. al., 2019)

Figure 22 is describing the interaction in a conceptual manner. Sensors embedded at the devices, which are for plant analytical purpose in usage (on the top-right), are transmitting the data via a network to a data storage, where the data can then be accessed for multiple reasons and stakeholders (illustrated in the centre).

With data analytics and research institutions the intervention can be executed, with the aim to monitor if the desired characteristics have been met, for example if the fertilizer usage of the crop in average have been reduced compared to conventional approaches.

Each iteration of data gathering, and its subsequent utilization is complementary in its production process, meaning the quality of data sets for predictive analytics increases with each iteration in accuracy. The machine learning algorithm for data analysis may not be good at the beginning, but the whole purpose of it is to improve itself over the course of trials and enhance the data quality and therefore the predictive data sets, which then again improve the algorithm. The next generations again will produce another data set and allow in-field experimentations, before the to-be-tested farming method is scalable in a commercial manner.

In field observations are way far more precise than the ones replicated in the laboratory, but more costly due to the architectural complexity of the approach. In laboratory generated data is only useful and useless in same extent, due to the fact that circumstances can not be simulated, which are not completely understood. Until now the chemical process of photosynthesis is not fully, but sufficient enough, understood and therefore create difficulties to replicate similar conditions in the laboratory. Meaning, the overall conditions concerning the gathering of data in the laboratory are very hard to be translated into on-field studies, and vice versa, the real conditions variables are very hard to simulate in the laboratory, due to the artificial environment. The results stemming from observations for crop cultivation from the laboratory could have diminishing quality for the usability in real world farming conditions. But with the gathered data, provided by the help of IoT devices, the field studies are a more naturalistic approach due to the biomimicry basis of observation and data creation.

The technology itself can be leveraged in several options, depending on the objectives of the digitalized farmer and farm. Data-driven insights into the natural biosphere enable for example to reduce the ecological footprint of the area where agriculture is executed. An efficiency-oriented farmer uses the data-driven technology in order to optimize in terms of profitability to achieve higher yields. Surely a coexistence of different objectives as well are thinkable and can be enabled through analysis of the observable parameters, depending from the underlying sensorics system in usage and the level of sensibility due to its function of the raw-data input for further data analysis (Dombrowski et al., 2019, Chanthamith et al., 2019).

The conceptual principle is very overlapping: The IoT connected devices allow an almost live monitoring about the status quo of the observed crops. The data inputs are feeding the algorithms, which are then supporting the farmer in decision making. Possibilities of sophisticated analysis is delimited by the sensor's technological capability of the parameters which the farmer wants to be recorded. The farmer receives notifications, if for example a crucial benchmark is over- or underrun, therefore solution and precise oriented actions can be undertaken, if wanted. Also a fully automatized farm appears to become more feasible, once the technology becomes more mature.

The results measured and gained from the laboratory, have to be enjoyed with limited relevance. Insights won´t be directly 1:1 implementable on the field, by the logic of the controlled environment in the lab, where plants received optimized nutrition, artificial light exposure, heat and water - which are not given in a real world case scenario. Nonetheless the digital technology, especially enabled through IoT, is a very good additional feature for future decision making of the farmer, due to the dynamical observation of the soil, plants and climatic conditions which allows timely interventions and gathering of new data sets. With every seasonal observation, the quality of the processed data enhances and is a superior basis for the subsequent point of discussion, for how the farm should continue and how to improve the individual farms situation, out of the status quo. This technology will help to drive the conventional farm to make the grace into the digital era and facilitates the adoption for the smart agriculture. The biggest advantage of this approach is the precise observation of dynamic real-world conditions, which generates a very expressive data set. The data sets created and observed in the laboratory conditions are from bigger importance in the case of in Greenhouse farming, to be discussed in the next chapter 2.5.3 In Greenhouse farming.

2.5.3 In greenhouse farming

Climate change and poor farming practices continue to degrade agricultural land. If this development continues, it may lead to more expensive farmable land, which will cause a rise of food prices. Greenhouses would be an eligible substitute against the threat if farmable land will become unfarmable. Like the other approaches of precision farming, it uses information technologies to increase the crop productivity and ensures that the plants and soil (if surrounding soil is even used) receive exactly what they need, for optimum health whilst using

fewer natural resources. The approach of greenhouse farming is to reduce the impact on the environment by cultivating crops in protected, optimized artificially conditions.
Additionally, this approach offers the opportunity to bring food into other places in the world where it is still a problem due to the harsh environmental condition's civilizations are facing, like in desserts. The technological infrastructure needed to realize this type are like in on-field farming, with additionally ventilators for the air circulation and light sources emitting in the exact frequency to maximize the crops growth (Farfan et al., 2019).

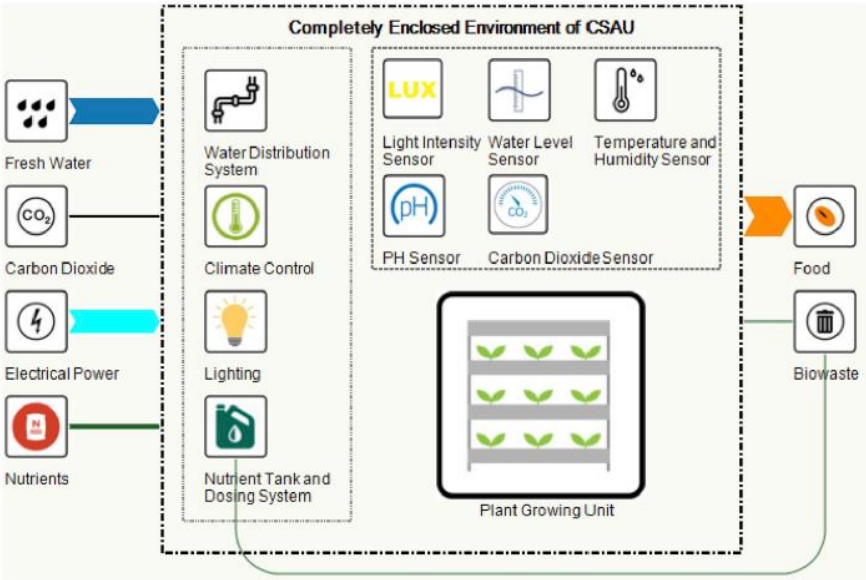


Figure 23 – Conceptual model with functional components of a greenhouse (source: J. Farfan et al., 2019)

Figure 23 is showing the necessary building blocks which are needed for farming in an enclosed environment. The system requires raw inputs as nutrients, energy, carbon dioxide (for the plants process of photosynthesis) and water supply. The various sensors are monitoring constantly if the environment is the optimal one for the specific crop in the plant growing unit. Controlling units deliver resources for the plants and adjust the nutrition timely, depending on the parameters provided by the sensors. After the plants are harvested, it is possible to grow directly the next pile of crops with few less time required compared by traditional farming. In the frame of traditional farming, the ground would have to rest and recover itself. A tractor would have to shake up the earth, called subsoiling, and if applicable also spray fertilizers in order to make the ground arable again. In a greenhouse this is not necessarily due to the conditioned supply of the ingredients. If the technology is available, this whole process of farming could be automatized.

To increase the crop productivity per square meter, it would be thinkable to pile the crops above each other in order to save space. Probably the term crop productivity per cubic metre would be more accurate. The data sets generated through this overall process can be gathered and then analysed with the help of Big Data analytics, which then increases the accuracy of predictions for optimizing the overall workflow. The greenhouses interior architecture differs from each another, depending on which type of crop is going to be cultivated and the water consumption is low, because over spilling water can be caught up and re-enter the water cycle (Mourik et al., 2019).

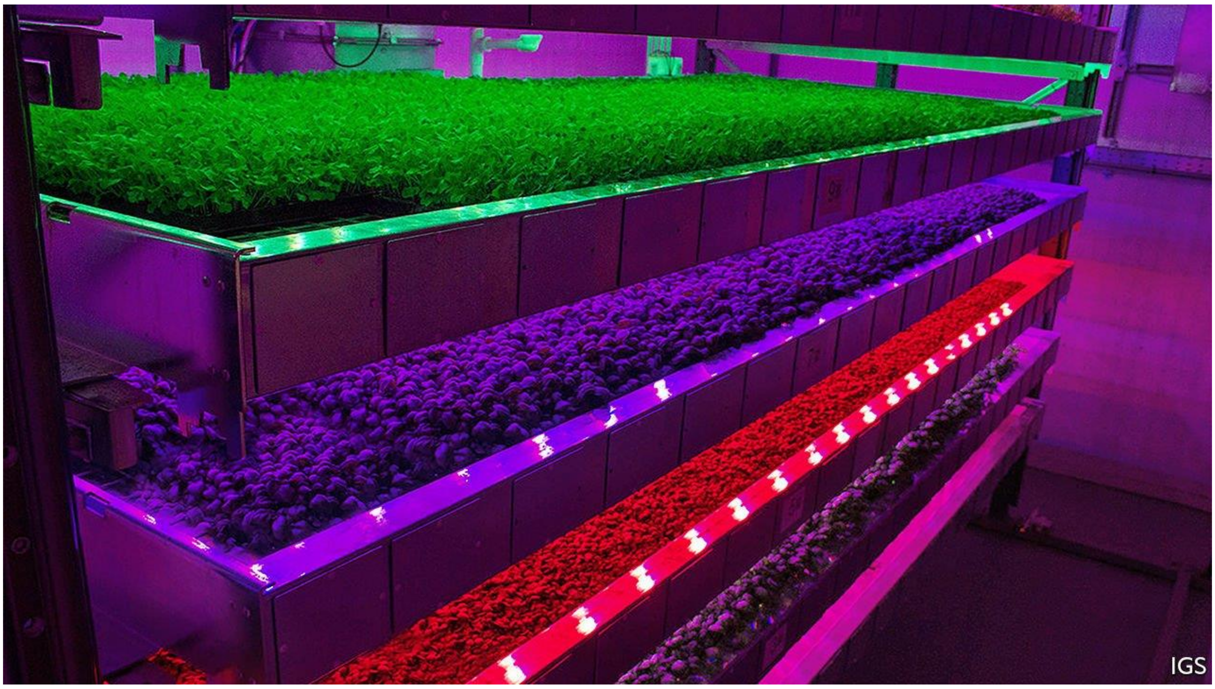


Figure 24 – Inside a greenhouse (source: economist.com/science-and-technology/2019/08/31/new-ways-to-make-vertical-farming-stack-up)

Figure 24 is meant to give an impression, how it looks like in such a greenhouse. Other types of greenhouses have transparent roofs, which allow even more reducing the energy consumption for farming. Greenhouse farming is a very promising idea to optimize farming, thus reducing resource usage and emission. It is a very creative approach, which allows many different implementations and the usefulness of the data should be very high, due to the controlled environment. Every subsequent plant generation can make use of the previous generated and analysed data, which increases the outcome.

2.6 Water

The management of water resources represents in farming a dual challenge. On one side, the global societies food demand is increasing, on the other side, the available water resources are decreasing. Water is essential for life on earth, but it is a very difficult resource to manage, due to the fluent shifts of it into different aggregate states and constant interactions with the environment. The main principle for agricultural water management systems is to increase more crop per drop, achieved either through smart water recycling or water-volume reduction on the fields. In the following an insight is going to be presented about the water management in agriculture. Starting with a look into existing water management systems, the benchmark crop water productivity and finishes with drip irrigation systems.

2.6.1 Evaluation of existing water management systems

Aqueducts have been already used in Italy for water transportation and facilitated the life of their citizens. Water management systems can help to allocate the water in a smart way and reduce therefore costs. Different farmers use different systems for the water management in their fields. One possibility is to store excessive water amount in dams, stemming from rainfalls, and release the water when needed.

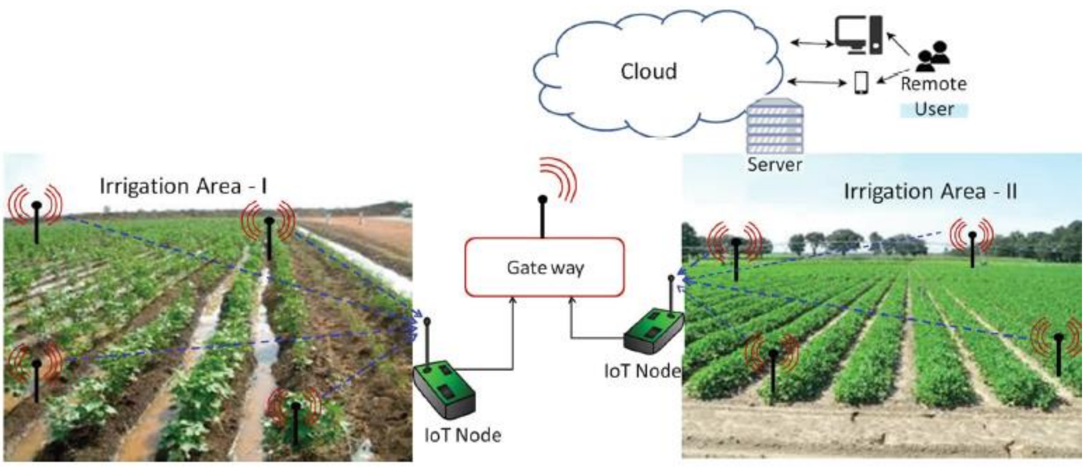


Figure 25 – IoT based dam water management system (source: C. Chellaswamy et al., 2018)

Figure 25 represents a smart water management systems for the agricultural sector based on IoT devices and cloud computing. This approach avoids water wastages and decrease the risk of running short on water in the future. The field contains at its edge a water disposal pit hole, where rain drops are collected which are falling outside of the cultivated field. It creates a storage system for the excessive water, which is not required when collected but may become beneficial at a point later in time. Several sensor nodes are installed over the field and are in communication with the cloud server via a transmitting network. The algorithm, to be seen in Figure 26, is evaluating through the inputs of the IoT devices if water is required to be released to the field, which happens automatically with the help of a controller. The released flow is based on environmental factors such as the soil moisture, sunshine, temperature and to-be-expected rainfall. In principal all kind of sensors from relevance could be connected to the system. Sensors within the lake where the water is stored can also be analysed to guarantee the quality and be spilled away before it may cause harm due to the cultivation of bacteria stems inside the water.

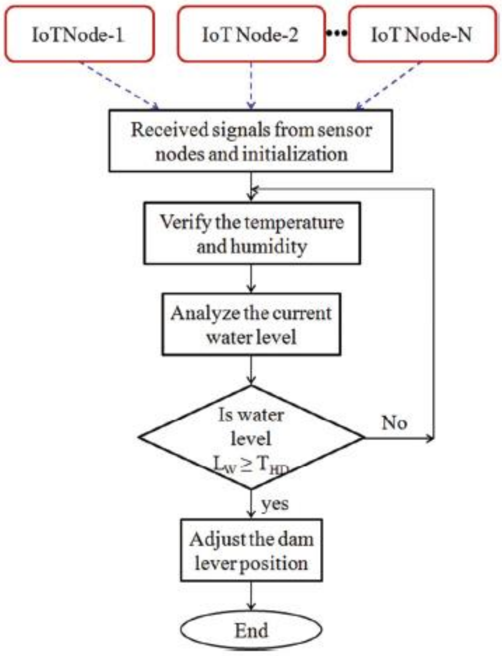


Figure 26 – Flow diagram of the water management system (source: source: C. Chellaswamy et al., 2018)

This is the flow diagram of the water management system developed in the study of C. Chelleaswamy. The study has been executed in India, and especially in developing countries, the digitalizing agricultures are precautionary integrating the possibility of storing water, to reduce the threat unexpected long heatwaves and diminish droughts could cause. With increasing analysis of the generated and collected data, the overall process will be able to be adjusted to enhance the likelihood of successfully cultivating crops, due to predictive analyses.

For example: if two days in advance rainfall is going expected, then it would be wiser to consider this fact before giving water. But also a different scenario is thinkable: if the soil has hardened already a lot (due to lack of watering), releasing a bit of water from the dam would be good in order to damp the soil, before the rainfall will hit the ground, and might be carried away immediately without reaching the crops roots (Chellaswamy et al. 2018).

The Smart Water Management Project (SWAMP) consists of an international collaborating team from Brazil, Spain and Italy, with the goal to develop solutions for precision irrigation in agriculture based on several technologies interacting together. In the perspective from the SWAMP team, farmers are irrigating precautionary too much, due to their fear of water stress for the plants. In fear of productivity decline, water is wasted because of the excessive giving. Measuring the soil moisture in real time of the fields and the crop growth stage (captured with images by drones), it is possible to determine exactly when and how much water is needed for the field.

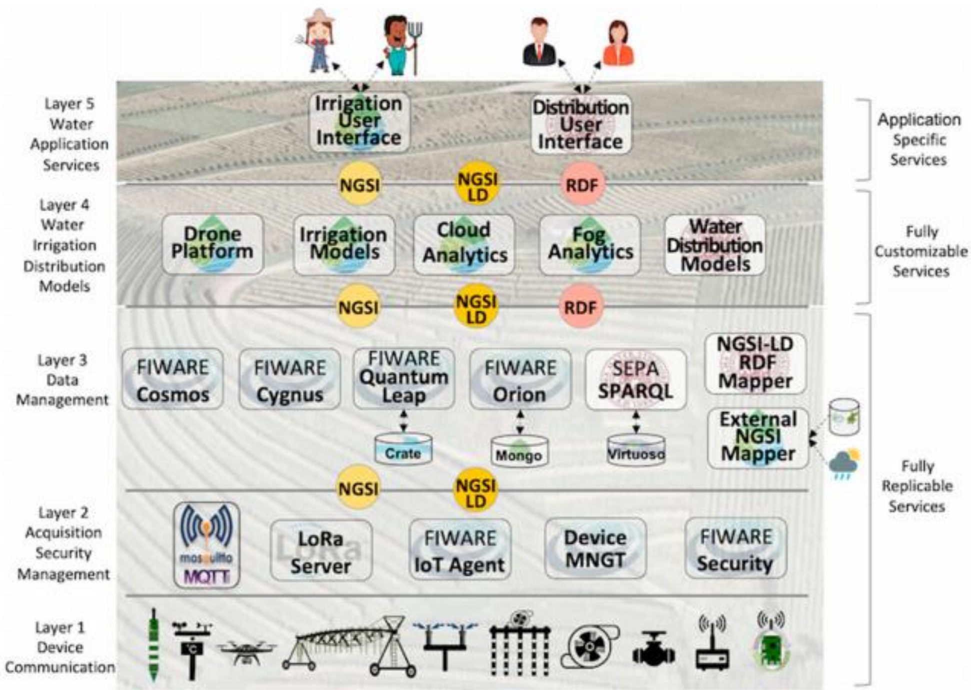


Figure 27 – The SWAMP concept, sliced in layers (source: C. Kamienski et al., 2019)

The SWAMP´s precision irrigation framework for agriculture is shown in Figure 27. The architecture is conceptualized in 5 layers: device communication, security management, data management, water irrigation distribution models and the water application services. This is the generical framework for the participating practitioners of the overall project.

Layer 1 comprises devices and communications enabled through varieties of sensors/gadgets for gathering information about the soil, plants growth, weather and as well the communication technologies (e.g. LoRaWAN). Layer 2 integrates data acquisition, security and management through protocols and software components. The FIWARE of the SWAMP project presents the data in the JSON format. Layer 3 takes care about the data management ranging from data storage, processing and distribution. Layer 4 is using optimization algorithms (e.g. Machine Learning) and techniques for the water distribution, based on data stemming on the plants water needs and finishes with layer 5 – the irrigation services for the farmers enabled by different interfaces. The conceptual model is meant as guidance for the farmers/participants, who would like to integrate the technologies into their farm (Kamienski et al., 2019).

The SWAMP project also has gone through first pilots in all of the participator's countries from origin (Brazil, Spain, Italy), but the documentation have not been very sufficient. Indeed it is a very young group of enthusiastic farmers and the published study lacks maturity. Water management systems are necessary for futurists farms to cut water waste and the so called drip irrigation systems are going to be presented in Chapter 2.6.3.

2.6.2 Crop water productivity

Crop water productivity (CWP) is a quantitative term, used for defining relationships between the crop produced and the amount of water involved in crop production and describes how much productivity increases with irrigation. It is a helpful indicator for quantifying the impact of irrigation schedule decisions about water management. Fast socio-economic growth combined with diversified diets across the globe and will continue the demand on already limited water resources and may cause conflicts over water due to the different stakeholder's interest. Increasing CWP is difficult to evaluate, due to the requirement of information about water use and efficiency. CWP varies widely within and between farms, due to underlying reasons attributing to many factors including rainfall inconsistency, soils physical properties, soil fertility, slope, and irrigation management. There is definitively a need for benchmarking of CWP relative to many factors, to support a better global understanding of where and how CWP can be improved. The literature varied about a standardized ratio concerning the CWP and every plant has its own specific CWP.

But throughout the different studies, CWP was mostly presented as a relationship as following: $CWP = \frac{kg/hectare}{mm/day}$. A high CWP is desirable and can be achieved by either increasing crop yield per hectare (with same amount of irrigation) or lowering the irrigation per day, but lowering the denominator too much may cause the crops death. In general the CWP gives a good approximation about the quantity of produced food in relation to the daily irrigation the field received and quantifies, if additional watering will or will not increase the yield of the field (Xu et al., 2019, Ezenne et al., 2019).

One study achieved to increase CWP by the act and idea of intercropping, which means to cultivate different plants within the same field. The idea behind intercropping relies in achieving complementarity characteristics on the field, by the crops natural differences in rooting ability, structure, heights, nutrient requirements and growth companionship – meaning no synergies are going to be achieved when one of the plants is ready to be harvested many weeks before the other ones reach maturity. The study has been executed in Kenya and the three plants used for intercropping have had been potatoes, lima beans and dolichos (another type of beans). Synergies have been achieved by mostly reducing the average soil temperature, caused due to a higher density of the crop leaves and therefore creating a brighter shadow over the ground, which then reduced the vaporisation of the water. No additional watering was provided and the field relied solely on rainfall. Digital technologies have been used for registering the climatic, environmental and soil characteristics data. CWP increased between 45-67 % in comparison when the crops would have been cultivated in a conservative manner and average temperature of the soil decreased around 7.3° Celsius. This experimental type of farming in Kenya could demonstrate definitively its benefits, but it has to be added that it increased an additional level of complexity when harvesting the crops. Thus, longer term effects are not yet known, due to overstraining the ground of three different types of crops could have a significant considering the soil nutrition. Nonetheless it is a creative idea to diversify the agriculture and with the help of data analysis the usefulness of this approach about CWP can be better evaluated (Nyawade et al., 2019).

Unmanned aircraft systems (UAS) carry the potential to increase CWP on fields through remote sensing, with thermal, multispectral, hyperspectral or thermal cameras. Pictures of the plants are captured by the UAS and sophisticated algorithms are evaluating the Crop Water Stress Index (CWSI).

The different type cameras can capture wavelengths, which are for the human eye non-visible, e.g. the photochemical reflectance or chlorophyll content, which are by the end of the day utilized to capture visible and invisible images of vegetation, in order to measure the crops water content. With this approach, the crops spatial and temporal variability can be measured in higher resolution compared to the already sophisticated IoT sensor devices. Insights gained out of the imaging processing algorithms are scheduling the field irrigation timely to create methods for early detection of crop water stress, in order to avoid irreversible damages. The conventional approach by measuring soil moisture is the most practiced approach but does not hold account for spatial/temporal variabilities. In times of strong weather conditions, UAS are not recommended to be used to the exposure of getting damaged while operating in the air. For further predictive data analysis, the data gathered through UAS and the captured images stemming from the cameras, are best utilized complementary with the data from the other environmental monitoring sensors. It offers a unique source which allow a deeper level of data analysis for optimizing the irrigation schedule in order to increase the CWP of the fields (Ezenne et al., 2019). The same plants show different CWP´s depending in which environment they are growing. Drip water irrigation systems are a helpful tool for watering the field and coming the ideal CWP closer. These systems are going to be introduced in the next subchapter.

2.6.3 Drip irrigation systems

Drip irrigation systems can help farms around the world to preserve water and save money, by supplying plants with exactly the amount of water they need. The water is delivered to the plants roots as proximate as possible in the form of small drips in order to reduce vaporisation and increase moisture. The idea was firstly introduced by Israeli farmers due to the necessity of finding a solution to grow crops in the dessert. Regarding different irrigations systems, farmers who are using these type of devices, reduce 90 % of crop evapotranspiration, when being compared with the conventional way of watering the plants. But not all types of crops are suited for this type of watering; e.g. maize requires full watering for growing (Food and Agriculture Organization of the United Nations, 2017). Additionally, this approach creates many savings because of the underlying water scarcity in the environment - when water is scarce, it becomes more costly It is a very difficult task, trying to find a precise mathematical description of the fluid dynamics for watering plants, due the jointly interacting factors transpiration, evaporation and interception.

Not considering the stage of the plant (a young plant needs less water than a half-grown one), the type of plant and of course the other external variables, such as sunshine, temperature and wind are all interfering with the evaporation, which reduces the effectivity of irrigation. The usage of IoT devices are indispensable to monitor the operations of drip irrigation systems for tracking all the variables which then allow the algorithms for calculating the optimizations.

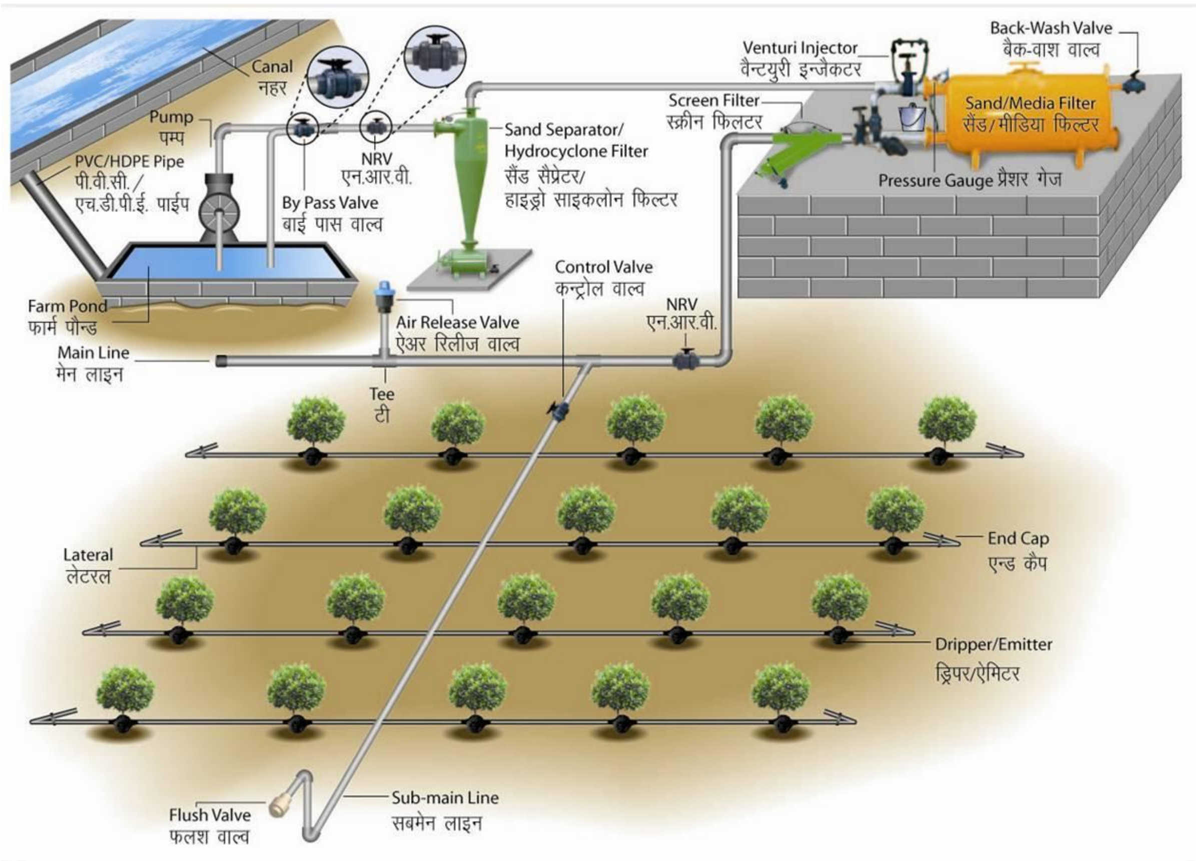


Figure 28 – Layout of a drip irrigation system (source: vikaspedia.in/agriculture/agri-inputs/farm-machinary/drip-irrigation-system)

Figure 28 describes the concepts behind the drip irrigation system. Every irrigation system begins with a water source, from where the water is transported through a pipe to the pumping station, which builds the pressure in the system. The filtration system ensures that the water quality is secured. A controller manages the irrigation process by delivering water to the main line, which then is divided to deliver water to the different field sections. Other types of irrigation systems include a fertilizing system, which adds the fertilizers to the transporting water in order to meet the crops needs. The water can be delivered to the plant in drops, but also other familiar forms of water transportation like sprinkling are also to be found under the label drip irrigation.

One study, executed in Spain, created and used a database for optimizing the drip irrigation for its agricultural models by sprinkling. In the conventional irrigation way proximately 30-40 % of water is not being properly utilized as it could, and at the maximum 60-70 % of water wastages could have been cut with the help of data analysis. The model was based on ballistic theory in attempting to describe how the water drops behave once they left the sprinkler for irrigating the fields. It included in its databases meteorological variables, like sunshine, temperature and wind, for optimizing the mathematical formulas for watering the crops. Any external variable has it effects on the evaporation of the water drops and therefore as well on the overall effectiveness for the crop irrigation. The experimental model included a self-calibration, which algorithms used the previously built databases in order to optimize the operating variables like sprinkling type, pressure, nozzle size according to the environmental condition. Regarding the results already after five iterations seemingly optimization could have been achieved in terms of the irrigation schedule and therefore reduced water usage for irrigating the fields (Robles et al., 2019).

Irrigation systems of the future are not only responsible for the water delivery from the source to the plant, moreover with IoT devices the external factors can be analysed which influence the irrigation of the plant. Mostly due to evaporation caused of high temperatures or wind, the water particles get carried away and the irrigation gets reduced. When the responsible external factors are recognized and the data is stored, then data analysis can help in creating an optimized irrigation schedule for drip irrigation systems, to increase the effectiveness and reduce water wastage - and the benchmark Crop Water Productivity should increase as well.

3. Suggestion of a strategy to push participation of European farmers to enter a data-sharing platform

Farmers are unfortunately reluctant to share their data (Wiseman et al., 2019). For the transition of the conventional way of farming into smart farming, the digitalization of workflow processes is from crucial importance for data creation, which then allow to analyse the data with the help of algorithms. If the algorithms are programmed well, opportunities for optimizations can be identified in order to maximize the performance of the farm, in respect to the external environmental characteristics in which the farm operates respecting the individual farmers objectives. This might result e.g. in less usage of fertilizers because the soil contains enough nutrients until the estimated harvesting of the crops or a disclaiming of watering the fields due to unexpected rainfall over the region within the next hours, which saves water and labour costs. With the integration of data analysis, the farmer can gain several benefits depending on the farms set of objectives. But in order to achieve this, the farmer has first to be willing to share the data to an external party, if the farmer is not able to run a server or the digital infrastructure by him/herself – disregarded from the additional financial costs such integration would bear. Data sharing platforms are especially targeting rural farms, due to the low switching costs in entering any of the platforms. Farmers can flexibly enter any type of platform and could cancel membership when they are not feeling satisfied with the cost-benefit trade-off. The reason, why farmers are so reluctant about sharing their data has several reasons. One of them is due to the lasting negative stigma data analysis undeservedly gained due to the Cambridge-Analytica scandal leaked in 2018, where personal data from over 50 million Facebook users have been misused. The other reasons causing the reluctancy are due to the lack of a regulatory framework resolving clarity and transparency of the terms and conditions; the question of ownership and sharing of data; privacy concerns; the inequality of bargaining power and a non-visible benefit of data sharing. (Wiseman et al., 2019).

These are the statements stemming from the interviewed farmers, but it has also to be highlighted, that the farmers in the study have been on average around 60 years old – if younger farmers would have participated in the study, the published consensus may have been probably different.

Additionally, it doesn´t compulsory mean, that once the legal, social and economic issues are resolved (clarity, transparency, ownership, privacy, inequality, non-visible benefit of sharing data), that farmers will join platforms immediately any of them without residual concern. In the following I will suggest a strategy in this thesis, how to push participation of European farmers to join data-sharing platforms, based on the model from Dr. Everett Rogers “Diffusion of Innovations”, a former American communication theorist and sociologist.

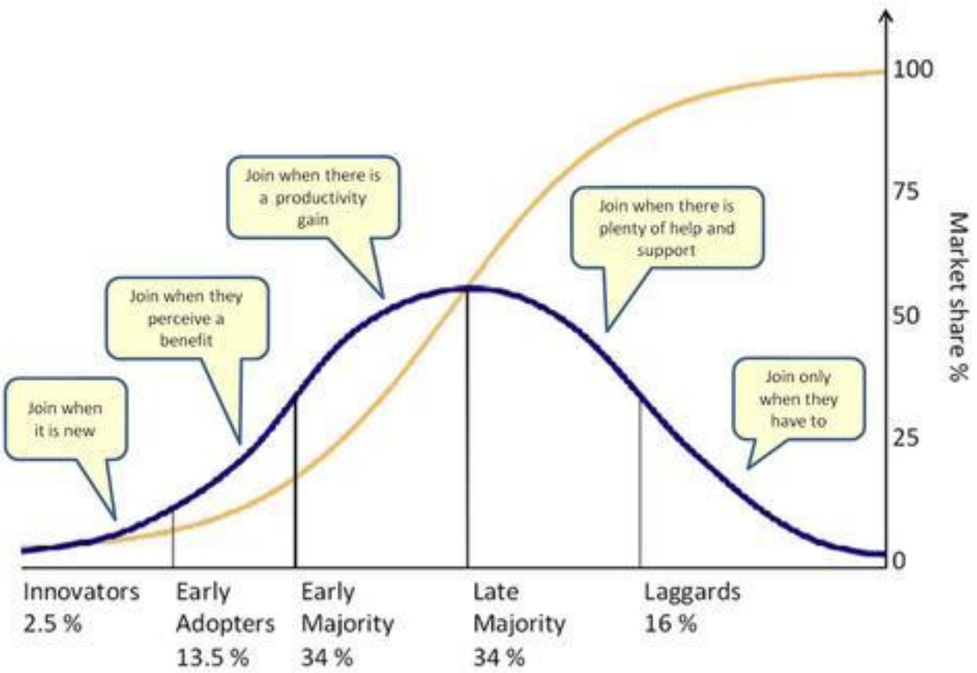


Figure 29 – Rogers´ model “Diffusion of Innovation” (source: informationweek.com/software/social/5-social-business-adopter-types-prepare-early/d/d-id/898950)

Figure 29 describes Roger´s model, which is a good approximation of the categorization about the perceived stages, how new ideas and/or technologies are generally spread. The transition from one phase into the other happens most probably fluently, but for simplicity it is divided in 5 categories: Innovators (2.5 %) is a broad term containing every set of action that contain ideas, practices or objects that any person (or other quantifiable unit of adoption) perceives as new, is considered as invention available for research. Innovators mostly include the creators of an idea/technology, which are willing to take risks. Early Adopters (13.5 %) are individuals, but also organisations or other social networking clusters and/or even whole countries. People within this category regard as having the highest degree of opinion leadership and are crucial for the further spread/outcome of innovative ideas because they function also as gatekeepers of innovation.

Early Majority (34 %) represents the group, which adopt innovations after a varying degree of time, which is obviously longer compared to the innovators and early adopters. Late Majority (34 %) adopt in general after the average participant, whose approach of adoption comes with a high degree of scepticism. Laggards (16 %) are the last to adopt to innovation and unlike compared to the previous categories, these individuals show little to no opinion leadership at all. If all categories adapt to the innovative idea/technology, then the market regards as saturated (100 %).

The original idea stems from Dr. Everett Rogers study on how farmers in Iowa (United States) adopted new ideas. He continued his study in other business areas as well and observed the patterns, how new ideas and technology diffuse through society and regards as a good approximation, within Management Engineering studies, in understanding, how innovation enters and establishes itself, independent from the marketplaces. Its shape cares many familiarities with Gauss´ normal distribution.

Farmers indeed do have a reluctancy to share their data – but how already stated the farmers interviewed in the study (Wiseman et. al., 2019) had an average age of 60 years. In my opinion it would be more beneficial, trying to attract younger farmers (below and within the range of 40-50 years) towards entering smart farming platforms. Young, professional farmers have the tendency to appear misrepresented in the studies I observed. Young farmers are many times consolidated as new entrants or entrepreneurs in agricultural related studies, which might lead to a wrong interpretation. New entrants or entrepreneurs are presumably expected to operate in smaller scale, due to the initial hurdles any kind of entrepreneurship inherently consists of. But especially when dealing with young farmers, this seems to be the opposite case. Young farmers manage larger farms, use more labour, generate higher value and age seem to correspond with farm size-structure within each European country. More farms are in ownership of older farmers, but the majority of these farms are very small (Zagata, Sutherland, 2015).

"A comparison of age cohorts with farm size demonstrates a relationship between the age of the farmer and the farm-size structure in each country. Almost three fifths (58.3 %) of the farm holders above 65 years of age farm on less than 2 hectares. Shares of older farm holders are rapidly decreasing with the growing size categories of farms. This is evident particularly from the view of the overall age structure of holdings according to farm-size categories. Fig. 4

demonstrates that small farms all over the EU27 are more likely to be managed by older farmers. The countries with a high number of small holdings thus appear to be more affected by the problem of ageing. This is typical of Hungary (79 % of holdings run by farmers above 65 years of age have less than 2 ha), Romania (68 %), Greece (59 %), Portugal (54 %) and also Slovakia (49 %). Generally, the greatest problem of generational renewal in agriculture can be expected in countries with high representation of older farm holders that in total manage a relatively high share of agricultural land." (Zagata, Sutherland, 2015).

The same study has written in another subchapter following: "Statistical comparison suggests that the low representation of young farmers in Europe limits the economics potential of agriculture, because holdings of young farmers appear far more efficient than holdings of older farmers, and their economic efficiency is generally above the European average." (Zagata, Sutherland, 2015).

It has to be emphasized again, that this study was back from 2015 and no other more recent published one could have been found in this category, analysing the diversity among European farmers – which is not misleading or incoherent for the purpose of my suggestion. If this trend was already observable back in 2015 (younger farmers outperforming older farmers), then the trend would have most probably continued over the course of time until the year 2020. The already economically stronger performing (younger) farmers gained probably more knowledge and experience in their profession (knowing how to manage larger parcels of land, how to produce more efficiently) without the usage of smart farming devices.

As far as my understanding goes – probably this segment of farmers are especially prone to the overall concept of smart agriculture. How the attitude of former "younger farmers" in 2015 developed over the course of the time is not yet known (or if they are still farming at all), but a lot of solution-oriented insights are gained by knowing, that these farmers are expected to be between 40-50 years old. Translating Dr. Rogers´ model to the nowadays times (2020), young farmers would regard as Early Adaptors (13.5%) and formerly younger farmers (which regarded as younger farmers in 2015) would regard as Early Majority (34%) today. As far as my understanding goes, this would be the right segments to be addressed effectively, when suggesting a strategy how to push European farmers to enter a data-sharing platform by segmenting the market by age.

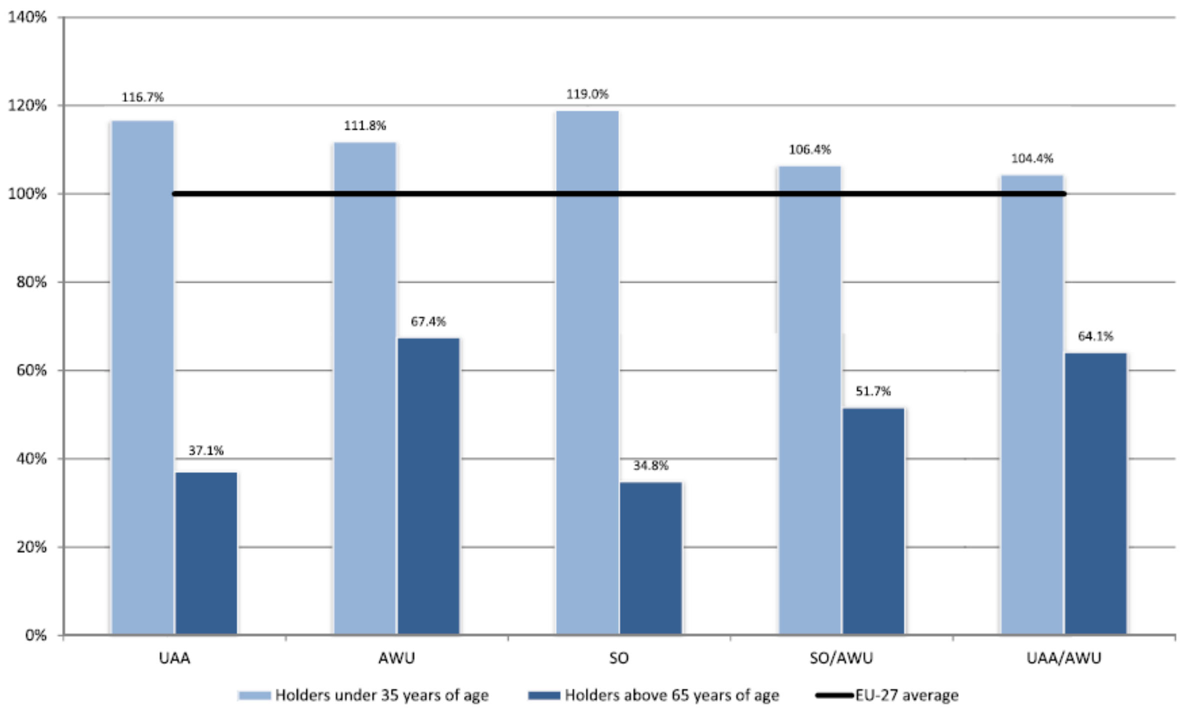


Figure 30 – Comparison of economic performance of farms by young and old farmers (source: L. Zagata, L. A. Sutherland, 2015)

This bar chart highlights in percentages the difference between economic performances of young farmers and older farm holders. UAA means "utilized agriculture area" and includes all kind of land categories (arable land, permanent grassland, permanent crop fields); AWU stands for "annual work unit" and corresponds to the work performed by one person who is occupied on an agricultural holding on a full-time basis; SO means "standard output" measured in Euro-per-Hectare. In every aspect young farmers are outperforming obviously older farmers, not only in quantifiable measures (UAA, AWU, SO), but also in the ratios SO/AWU and UAA/AWU. The ratio SO/AWU is to be interpreted, that young farmers are utilizing the same agricultural space more profitable compared to older farmers (working smarter, are more careful about the resource utilization); and the ratio UAA/AWU is to be understood that younger farmers are working more efficiently than older farmers. Older farmers would have to work more hours in order to achieve the same level of output than younger farmers. Vice versa younger farmers are allowed to invest less labour for generating the same amount of output produced by older farmers. This ratio compares very good the efficiency between old and young farmers.

Once again it has to be stated, that this research paper stems from 2015, but it has to be added that also until the year 2015 the overall idea behind IoT, the interconnectivity of automated processes or data analytics was very far off the mark. With this I try to say: older farmers are not necessarily reluctant sharing their data, furthermore they are (still) reluctant toward innovation/innovative ideas in general.

Based on Rogers´ model "Diffusion of Innovation", that early adopters can be regarded as gatekeepers of the success of any innovation/idea (due to the opinion leadership) and the already pre-existing trend stated back from 2015, that younger farmers are outperforming obviously older farmers (in the European Union), I suggest strongly: any type effort undertaken, in order to push participation rates among farmers to join smart farming platforms, should be addressed towards farmers younger ages. Not that the market segment about older farmers would not be important where agricultural data can be gathered and analysed for improving the workflow, but mostly older farmers are clinging to their old fashioned attitude due to emotional and inheritance reasons (not interested in selling the hectares of land to non-family members or other farmers in the hope, the price-per-hectare is going to increase over time due to scarcity) (Zagata, Sutherland, 2015).

It is by logic more efficient and longer-term oriented, introducing especially younger farmers to smart farming approaches of various kinds, rather than convincing older farmers to change their way of operations. And if the older farmers intend to remain compatible in the long-run with the younger farmers, then they would be inevitably forced to upgrade their set of technologies in order to remain compatible in their rural area due to market forces, which would establish in the long-run due to the demand-supply-equilibrium. In the following I want to present three different potential customer touchpoints, where the providers of smart farming platforms can try to reach out to the potential prospective European clients in the future: Agricultural education centres, agriculture conferences and agrarian IT schools.

In most of the countries of the European Union, agricultural colleges are present which facilitate learning for all the individuals who intend to pursue a career in the agricultural sector. The colleges are learning centres where the exchange and transfer of knowledge is facilitated by teams of professional teachers in land-based education and provides adequate trainings. The aim is to develop professional key competencies for the students (e.g. flexibility, adaptability, entrepreneurship, social skills, communication skills) - requirements which the farmer of tomorrow needs the most due to a fast pacing environmental landscape, necessary to maintain the food security. Modern training in agriculture ensures the future of people in the land-based sector and is therefore representing the basis in a viable rural area for sustainability. Students at European agricultural colleges learn through a combination of theory and practice, delivered within the college and in industrial placements. The students are trained to keep the balance between economic demands and environmental issues.

Agricultural education will become the most important resource in world-wide competition in the opinion of the European agriculture education centres, due to the many upcoming requirements caused by rapidly changing environmental conditions. Therefore, in my opinion, it would be a very good starting point for smart farming platform providers to promote their idea. European agriculture schools are offering the right environment, where the conceptual ideas and benefits can be introduced in an adequate manner. The young students could also become trained for developing the cognitive capabilities for understanding the necessity and importance for data sharing. If they are not joining smart farming platforms by the end of the day by themselves, most likely the students are going at least to spread the idea behind it and raise awareness about the overall concept which then might cause an increase in participation.

Another option, the most habitual one, for smart farming platforms to promote themselves would be on agricultural conventions. Across Europe there are many agricultural conventions, where producers of products and technology related to agriculture are presenting their ideas and concepts. They are wide ranging, from fertilizers until cattle management, but the most appealing for smart farming platform providers would be most probably the digital related agricultural conventions. But in order to reach out a bigger audience and raise awareness about the existence, basically a presence at any type of the conventions would be constructive for the concept of smart farming and the concluded data sharing. Agriculture conventions are held in every potential realm of farming itself. This would represent a touchpoint especially targeting the farmers in the age between 40-50 years, according to Rogers´ model the Early Majority.

The last option, where potentially interested farmers could be found, is at agrarian IT-schools. Remote platforms are aiming to reach out to rural farmers, which are not flexible to visit any building centre in person due to the intensive amount of labour. Different universities are offering as part of their online presence courses for agriculture. The “Lakeshore Technical College”, “University of Illinois” or the “Washington State” universities would be an address for farmers and interested ones to participate in one of such programs for enlarging their professional horizon. It could not be evaluated if the opportunity for advertisement on behalf of smart farming providers exists, or either if the concepts smart agriculture and data sharing are contained in one of the courses, but nonetheless they can present another potential customer touchpoint for keen technology interested farmers. Farmers which are not open minded for innovation are probably not spending time and/or money on one of these platforms.

One evidence-based study could have been found, which was conducted in the Northwestern region of Italy, Piedmont. The researchers are stating as following: “The analyses showed that low levels of education and working on-farm alone were positively associated with perceived economic barriers, which in turn were negatively associated with the adoption of SFTs. Farm size had a positive direct effect on SFT adoption. The results pointed out the need for targeted policies and training interventions to encourage the use of SFTs.“ (Caffaro, Cavallo, 2019).

SFT is the acronym for Smart Farming Technologies and the farmers interviewed in this study had been on average 40 years, and worked about 20 years in the field of agriculture; the farmers therefore were on average 20 years old. With these 2 facts I try to point, that an early introduction to the concept of Smart Farming to the farmers in future could have an important impact on the future decision making of the individual farmer, when addressed early enough at the places he/she is expected to be. In my opinion, the most convenient one would be agricultural schools.

Definitively no farmer can be forced to integrate any type of digital technologies in his/her enterprise and consequentially share the data afterwards in the interest for the public stakeholders. In any other business as well, privacy policies play an important role in order to protect the consumer against exposure against his/her will. But especially in the agricultural sector this is an important factor, which might be necessary to secure the future of farming at all. If a data sharing of gathered data is not happening at all, this might cause a big threat and cause an overall collapse of the ecosystem. In economics this phenomenon is better known as the “Tragedy of the Commons”.

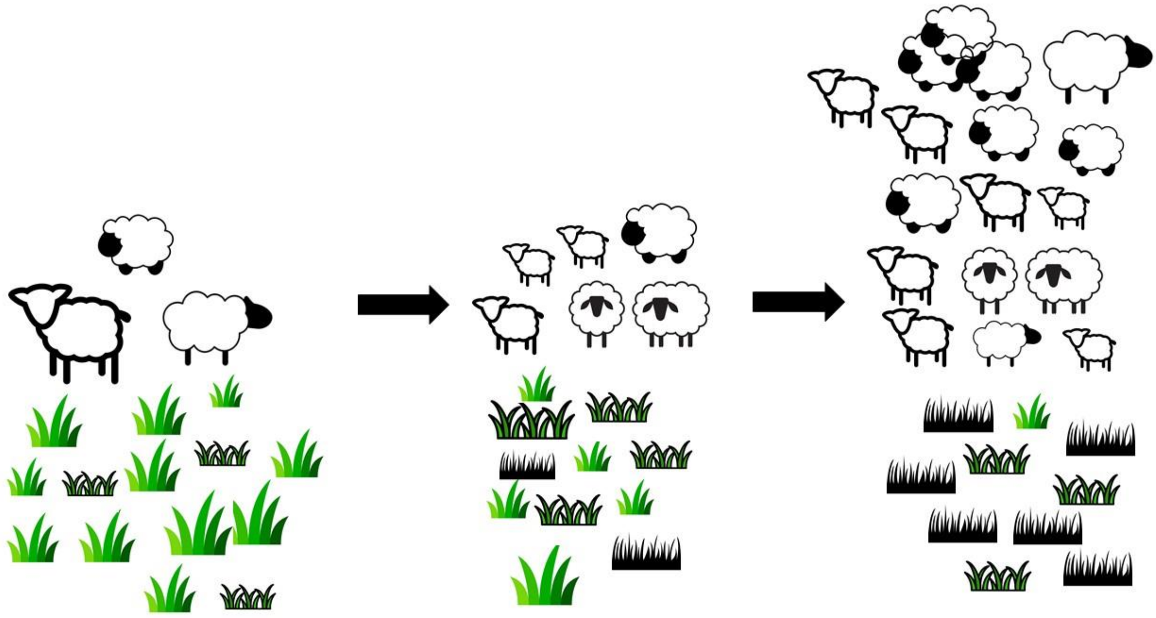


Figure 31 – The Tragedy of the Commons in the case of overpopulation of sheep and grassland

Figure 31 is conceptualizing the "Tragedy of the Commons" for the case of shepherds (or a highly intelligent self-organized sheep tribe) which let graze their sheep on the grassland. In the first step, the use of the commons (the grassland) is below the carrying capacity of the land and all shepherds benefit. If one actor or more (the shepherds) increasing the use of the commons beyond its carrying capacity, the commons start to become degraded and the cost of the degradation of the grassland is incurred by all the users, visualized in the second step. Unless environmental costs are accounted (the degradation of the common) and executed in land use practices, eventually the land will become unable to support the activity, which is demonstrated in the last picture.

The "Tragedy of the Commons" is the idea stemming from Garrett Hardin, a Microbiologist, back from 1968. It refers to a scenario where selfish utilization of resources by an individual ends up having negative effects on the entire community. Translated to the case of farming this means the individual farmers reluctance to join a smart farming platform and keep the data for him/herself, which contains less intrinsic value if the data is not mined/analysed. The individual agents private and selfish needs are legit to exist but on the other hand, the whole community´s collective interest may not necessarily the same as the individual agents one. The tragedy of the commons affects continuity of life in an ecosystem, where unregulated consumption can affect the community negatively. When data will be collected and available for further analysis, cross-correlations of farms can be detected which would remain unrecognized otherwise. The overly usage of fertilizers from one farmer could have effects on the groundwater and influence the water source of another farmer, without each other's awareness of influence. Or a disease may already infect other farmers cattle by the time the first farmer recognized the disease in the own herd, whereas with the help of digital technologies, a change of behaviour can be recognized earlier and preventive actions can take place timely to reduce the likelihood of the spread of diseases or negative developments.

Tragedy of the commons occur when people are given too much freedom when it comes to making choices about resource utilization, which may lead to the overuse of various resources and introduce the inability of an ecosystem to sustain itself. Digital technologies carry the opportunity of better recording of the resources in many thinkable manners and a digital representation of the overall workflow processes can facilitate a sustainable handling with the limited resources. One cause, how the tragedy of the commons occurs, is due to the egocentric perspectives. The "Tragedy of the Commons" could also be resolved without any technological intervention, if the actors would learn the virtue of sharing and avoiding egocentric actions for the benefit of everybody in the interactive society. A change of moral values in individuals would be required, but it is a very imprecise solution and does contain a lot of uncertainty about the success´ outcome. Nonetheless, one cannot be prevented from using a given resource until a substitute is presented and therefore the "Tragedy of the Commons" requires a technological solution in order to be averted. In the case of substitutes for farmers to reduce egocentric behaviour, smart farming platforms and data analysis would represent such substitute.

Especially data analysis is evaluating the circumstances of the operating farm predictively. The data recordings enables the underlying algorithms to recognize reoccurring patterns faster and more accurately than they would probably by solely human observation. Solution-oriented technological changes can take place in order to avert the downfall of the ecosystem. A downfall of the agricultural ecosystem would mean that weather, water and soil conditions would become irreclaimable, that no crops would be able more to grow. Many participants are contributing indirectly to weather and water related shifts, but especially soil changes are directly caused by the farmers actions or inactions. A depletion of one resource can lead to extinction of various organisms and the tragedy of the commons is catastrophic to the community, with incalculable consequences.

If smart farming platforms aim to establish themselves within the agricultural marketplace, it needs definitive to address the customer touchpoints directly. It will require talent in order to convince the farmer to enter the platform, even when the long-term consequences of integrating modern devices and technologies (IoT, data analytics, automatization, blockchain) are extraordinarily beneficial. We as humans tend to be habitual and underestimate the future due to the inability to think in exponential terms. With this I try to say: it will be probably difficult to convince the farmer to adopt the technology unless he/she would see a quick benefit. For every hectare digital technologies are utilized, the farmer may risk the profit he/she believes to make in a conventional manner.

Farming and agriculture are by itself already small miracles, because just by raw imagination it is hard to believe that any type of crop/cattle has the potential to multiply with the help by economic means. Education, patience, and knowledge transfers are the necessary bridges to manage the gap between fiction and reality. And the best option in order to spread the idea behind overall smart farming concepts, including all underlying digital technologies which enable data analytics in agriculture, relies in my opinion by addressing the young farmers attending the agrarian educational centres all across Europe. If they want to be competitive with the incumbent farmers in the marketplace, what I strongly assume, then it would be for the own benefit to integrate the supportive digital technologies in their enterprise. And if the established farmers are afraid of losing their market share and potential profits, due to the highly technological equipped younger farmers, then they inevitable would be forced to upgrade their set of technologies and share their data. The other channels (agriculture conventions, IT-schools) would be complementary to raise awareness about the existence and idea of smart farming.

4. Connecting the dots: from Smart to Precision, up to the dream of Decision Agriculture

To implement the smart agriculture of tomorrow, it would be definitive from advantage to align on standard protocols in order to guarantee smoothness communication between the different interactive participants, which is difficult to realize due to the high number of different agriculture product providers. Every producer is incentivized promoting understandably the own product. But on the other hand, this might hinder to agree on standards in common interests and might lead to the development of the agricultural market to a “winner-takes-all” scenario, which would be an unfortunate outcome. A “winner-takes-all” market describes a market, in which the best performers are able to capture the majority of market shares, while the remaining competitors are left with little or nothing. An expansion of “winner-takes-all” markets contributes to a spread of wealth disparities, and the market becomes dependent on the dominant incumbent within the ecosystem, which vice versa is defending his position and may block innovation.

The agricultural sector is a very big market and in my opinion it is very unlikely for a single company to become the dominant actor saturating the overall demand, providing the farmers with one type of machinery and coding a unique protocol, which would be necessary for digital communications. Additionally, the coexistence of the different farm types increases the level of complexity. Each farm differs from another. It would be an impossible challenge to produce any type of machinery or digital technology, which is sufficient enough to fit the requirements for all the existing farms over the marketplace. Until now, no specific or dominant data type could have been found, preferred for data related applications in agriculture, nor a recommended used protocol for IoT devices. Many bodies are active doing research for pushing advancements for enhancing developments.

In my personal opinion it is definitively worth to continue the effort for standardization of data types and communication protocols between the IoT devices, in order that communities will be able to make the jump from conventional farming, to Smart Farming, to Precision Farming up to the dream of Decision Farming.

Smart Farming is still in its infancies and this thesis tried to provide a systematic overview of the already achieved milestones a digitalized agriculture could look alike. The principle summarized in a few sentences: Smart farming focuses on the development of rural and agricultural production enabled by better knowledge and communication processes. In particular it consists of conceptualizing, planning, implementing and the application of agricultural workflow processes in creative ways, using information and communication technologies. The usage of these technologies approaches to help farmers to increase profits by achieving higher efficiencies or reducing operational risks. Due to the undertaken research I have done, I can confidently say to have understood the overall trend, where the future of agriculture farms seem to merge with each other: a decentralized agricultural cluster, which moves away from industrialisation approaches towards sustainability and creating synergies with nature.

We should work with the nature, not against it. In the sense: to leverage the processes which are naturally occurring, instead of exploiting the environment and provoke unsustainable growth for short term profits by industrialized approaches (mixing the cattle food with antibiotics, overly use of agrichemicals). Obesity-related deaths are occurring three times more than fatalities due to malnutrition or starvation. Indeed, too much food is produced rather than too less, but its not equally shared among the globe as it should be. Furthermore, farmers which are operating under difficult circumstances (like extended heat waves, water shortages) face indeed already difficulties producing food. Therefore at these farms, logically the capital and/or time is missing for improving the farming methodologies and the level of education of the farmer. The centres of food production are mostly concentrated and agriculture production is at the highest level it has ever been. Also, a lot of animal food, in the form of wheat or soya beans, is produced for feeding cattle, which are cultured in mass production systems. Every ecosystem is naturally limited by its biological frontiers and growth cannot happen unlimited without other, yet unconsidered costs.

In economic systems it makes sense to focus the food production in one area (due to economies of scale), but this also increases the overall risk of the food-security system. If a big agricultural producer is hit by an economic shock, the overall systems risk of downfall increases. Recently, due to the Covoid-19 crisis, US farmers have been forced to cast away edible food because the enterprises faced difficulties finding any purchaser. It is for the farmer economically more expensive to give the food away for free due to packaging and food-logistics. Unfortunately, the farmers had to throw it away with the hope, the next harvest will have purchasers in usual amounts. Surely, a decentralized farming framework would bear in theory a similar risk of external economic shocks, but it is unlikely that the economic shock would hit each farm in the same amount and farms are continuing to produce food in order to satisfy the markets demand. With the example of the Covid-19 crisis and the farmers reactions in the US, I wanted to emphasize towards which irrationality farming unfortunately developed over the course of time. Farming and the food production does not appear for me to be anymore about food, it´s simply profit-maximization for short-term profits without considering the long-term consequences.

Due to overexploitation of the arable land for increasingly short-term profits, enabled through the overproduction of food in one area, the hectares may not be arable the subsequent seasons, which could threat the ecosystem to survive. Surely, these cases I introduced have been very pragmatic examples, but I want to warn that the European Farming Framework may not develop in a similar direction as the farms in the US apparently did.

Interestingly, indeed a study is aligning with my own, above formalized statement. Before I found this study, I had already doubt about the sustainability of the industrialized way of farming, without being able to present any evidence for strengthening my point of view. The study appears to be very reliable due to the effort of over 29 researchers who contributed to the paper all over Europe. Agroecology's in Europe, which practice nature driven approaches, have positive correlations between sustainability and increases in employment and income levels, compared to the conservative-industrialized way of farming (van der Ploeg et al., 2019).

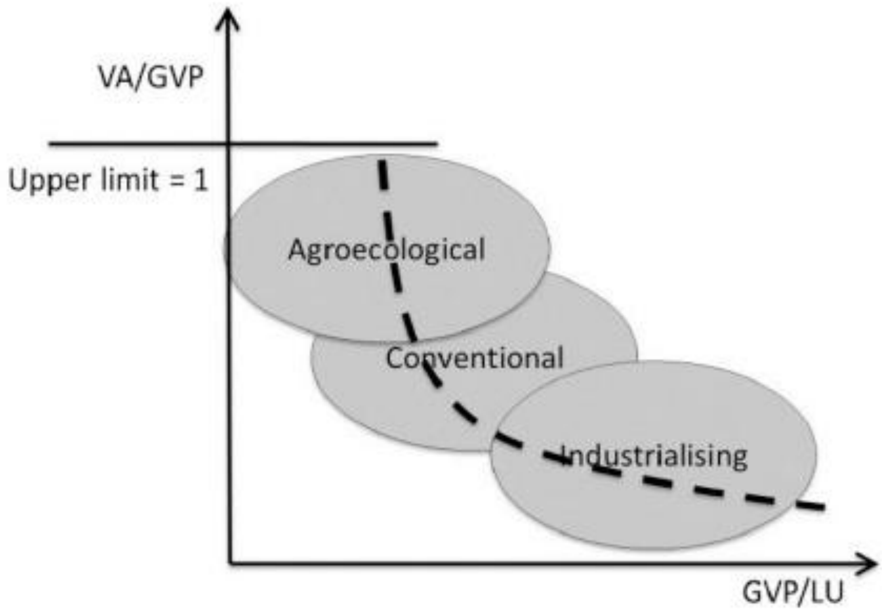


Figure 32 – Relationship between Value Added (VA) and Gross Value of Production (GVP) across the different way of farming (source: J. D. van der Ploeg et al., 2019)

Figure 32 represents the plotted graph of the results, behind the research undertaken by J.D. van der Ploeg et al.. GVP expresses Gross Value of Production, LU is for Labour Unit and VA stands for Value Added. On the x-axis the ratio $\frac{Gross\,Value\,of\,Production}{Labour\,Unit}$ is represented and on the y-axis the ratio $\frac{Value\,Added}{Gross\,Value\,of\,Production}$. The graph highlights the inverse relation between VA/GVP and GVP/LU, where the crossed-out line presents the trend. The elliptical sections are for framing, in which way of farming the results got obtained. The three ways are: Agroecological, Conventional and Industrialised farming.

An inverse relation between VA/GVP and GVP/LU is obvious, which has to be understood as following: An enlargement of the total production per unit of labour force on the x-axis (GVP/LU) requires usually investments in new technologies, especially an increase in input-levels (labour force, seeds, fertilizers, water, hours, cattle, machinery). Consequently, the variable costs due to the higher input-levels (fertilizers, water, hours, seeds) will rise as well, and the Value Added (VA) will go down. Under strategies that aim to increase VA/GVP ratios, a further expansion of the resource-base is difficult or even impossible to achieve.

Under an Agroecological approach it is not possible to produce more food, than the utilized land is able to give, due to the efficiency principle in the law of physics. Therefore, the upper limit is equal to 1, between Value Added and Gross Value of Production.

All input made (Value Added) contributes to the Gross Value of Production, when the ratio is equal to 1. Whereas under Industrialized and Conventional farming approaches, an extensive use of resources would be necessary to enlarge the Gross Value of Production, but regarding this study the Value Added (in the food production) becomes reduced, which definitively does not appear to be sustainable in the long run.

Conventional and Industrial agricultures would need to continuously expand by taking new debts. The debt-driven growth decreases with each iteration the proportion of Value Added for the farm. If continued like it used to, it leads to the emergence of Diseconomies of Scale, rather than Economies of Scale, which bigger scale farms are stating to aim for. In theory, Economies of Scale are achieved through cost advantages that any enterprise obtains due to the bigger scale of operations.

But apparently, in the agricultural sector, a bigger scale approach seemingly leads to the opposite case, as Figure 32 captures and causing more costs in the long-run than the sum of the short-term profits.

Agroecological farms show income levels relational to undertaken input and are outperforming the Conventional/Industrialized farm enterprises. Agroecological farming is especially appropriate in helping farmers against the deterioration of the land and help to face adverse outcome no farmer aims for. The “Tragedies of the Commons” becomes reduced or even solved. It must also be emphasized, that Agroecology practices are not only ideas how to involve the processes with no or few chemicals. It emphasizes the development and maintaining an autonomous resource-base, with on-going improvements of resources within the farm itself. On-going learning processes and the establishment of interacting cycles that produce synergies between the incentives of the operating farm and nature (van der Ploeg et al., 2019).

Traditionally, farmers would have to go to the fields for checking the status of their crop and/or cattle. If changes are necessary to be made, then they are based mostly on their accumulated experience over the course of time, without guarantee if the formerly made decision was right or wrong. This approach is no longer sustainable as some fields are too large to be efficiently managed in order to comply efficiency, sustainability and food-security. With this I try to underline my point, that also Conventional/Industrialized farms will have to integrate digital technologies in their workflow processes, solely for the survivorship of the farm itself, irrespective of Agroecological reasons. With farm size, so does the level of complexity increase and may cause intercorrelations, which then might cause difficult ascribable problems.

Despite some individuals´ long-time experiences gathered through many years of work in the field, technology may provide a systematic tool to detect unforeseen problems, which would be else hard to notice alone with the help of visual inspection at frequent controls. Unconsidered the higher economic efficiency of younger farmers compared to elder ones, younger farmers show also a more positive attitude towards smart tools providing information of relevance, according to the study by the European Network for Rural Development.

The information retrieved from crops/cattle can be turned into profitable decision making when managed accordingly. As stated through the course of this thesis, information is acquired through sensors with the aim of maximizing productivity and sustainability, which allow data-bases to grow and become more accurate for further usage. Data-driven agricultures are offering incorporating the breakthroughs achieved by artificial intelligent systems and set the cornerstone for the agriculture of the future to happen.

Digital technologies utilized in smart farming approaches have the big potential, to translate the core values of Agroecological farming into Conventional and also Industrialized farming, in order to guarantee the food-security supply chain in a sustainable manner, so the earth resources for producing food are not overused and no economic deficit will be caused in the future. But also, they can help to scale Agroecological farms, in order to keep their core values and satisfy the food demand in their rural area.

Evidence, if digital technologies have been utilized at Agroecological farms, could not be found. But with this graph in Figure 32, there is obviously the trend, that a back-to-the-nature driven approach is economically speaking also more appealing and by integrating digital technologies, into the workflow processes in the farm, the production has the potential to create synergies with nature. But for this to happen, first the farms have to upgrade their set of machinery and include digital technologies (sensors, IoT devices) on their fields. Additionally, legislative/personal barriers have to be overcome in terms of data sharing issues.

As well farmers have to be convinced to use smart farming approaches and sharing their data, which is more efficiently achieved in my opinion when younger, ongoing farmers are addressed with the values and benefits data sharing bears at agricultural education centres, rather than pushing incumbent farmers to make investments, as already explained in Chapter 3.

But in my opinion, the future framework of agriculture in Europe bears the potential to look alike as following, expressed in a graphic:

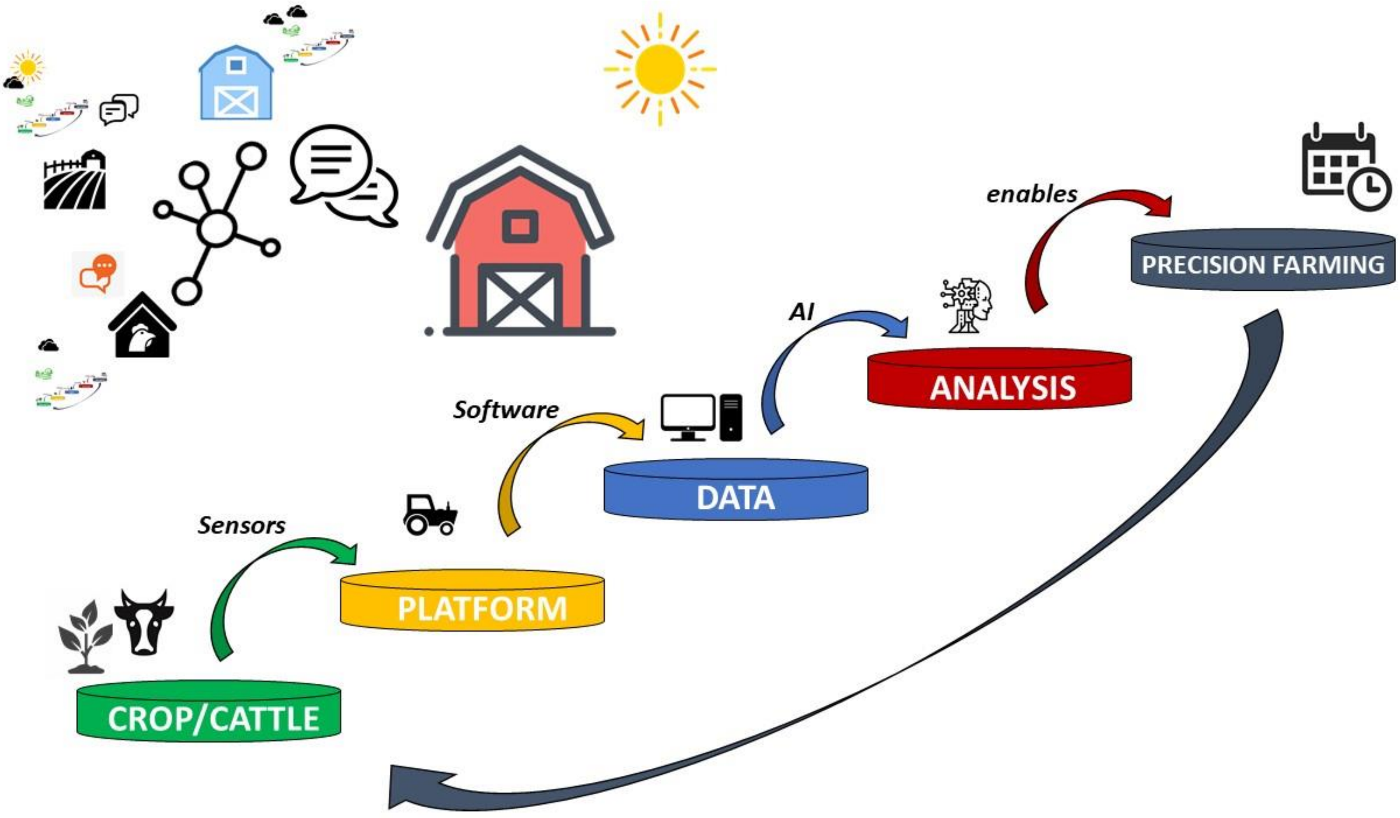


Figure 33 – Information-based cluster of Smart Farms, interacting with each other in order to enable Decision driven farming

With Figure 33 I tried to present my opinion, how the future farms could collaborate with each other interconnectedly. The workflow process from the Crop/Cattle management up to the level of data analysis are demonstrated in a macroscopic view, in order to optimize the underlying operations according the objectives of the farmer. When each farm integrates a Smart Farming system in their enterprise, a higher level of accuracy and data quality can be achieved. It could occur, that events affecting Farm Y will may cause effects on Farm B, even when the farmers are not even aware of the correlation between them both.

In theory, Nash Equilibriums could be easier achieved when the farmers are trusting their underlying systems, that every digitalized farmer is using exactly the required demand of inputs (labour, nutrients, soil, water, energy) by the help of precision farming techniques in order to produce exactly the amount and type of food the market demands – Decision Farming. As Nash Equilibrium describes the solution of non-cooperative games involving two or more players and no player has anything to gain by changing only his own strategy.

Definitely, the agricultural sector is too complex by the farmers to achieve Nash Equilibrium without the help of data analysis and digital technologies. No individual farmer has the capacity to process the infinitive appearing amount of relevant information by him/herself. But with the help of the digital technologies, described in the previously chapters and subchapters, the theoretical goal of a dynamic-interactive correcting agriculture, which is not overproducing too much or too little food, becomes practically more feasible. When the Blockchain technology will become integrated as well, then a predictive agricultural system is in theory applicable, where every citizen receives based on his/her nutrition requirements and diet exactly the amount of food necessary. The Blockchain technology has the possibility to substitute food stamps in an economy.

The earth will be given the required amount of time for recovering itself and the food-security systems are adjusting itself based on the environmental conditions. No farmer would have the economically incentive to act unfair in the long-run. Furthermore, the farmer is incentivized to act favouring sustainability and nourishing the data pool for further improvements of the systems and increase the performance of the data analysis for the benefit of the upcoming generations.

Exactly the necessary amount of food will be produced of what, when, to whom and where it will be needed the most. This is the dream of a Decision Agriculture, but as stated in previously it is an opinion provided by me. In order to achieve such level autonomous cooperation, farmers of course first have to integrate Smart Farming approaches.

For farms, which are operating in the US or Europe, no evidence approving the benefits of income, for any type of cooperation, could have been found. But in developing countries such as regions in East Africa and in Asia (Taiwan, Japan), cooperating farms are creating indeed positive externalities. (Grashius, Su, 2019, Bolton, 2019, Yung-Hsian et al., 2019)

"As such, almost all studies reported a positive yet heterogeneous impact of cooperative membership on income. However, with farm size as the mediator, there is no consensus regarding the exact direction of the heterogeneous impact. Also, all the empirical evidence is generated in the developing world. It is unknown if cooperative membership in Europe and North America, where the agricultural market is arguably less characterized by market failures, also facilitates a positive impact on farm income or if the impact is comparable in magnitude to the effect in the developing world." (Grashius, Su, 2019).

5. Conclusion

This thesis aimed to give a systematic overview of how humans, machines and digital technologies can efficiently collaborate for growing food to feed people. The latest industrial revolutions mainly focused solely on the mechanization of processes for increasing efficiency, but this approach is no longer viable for facing the expected population growth in the coming years, while integrating sustainability in the overall workflow processes to reduce the environmental harm farming is contributing to our planet in the most efficient and respectful way.

For facing this challenge, remarkable advances in technologies keep appearing since the latest years. Reliable agricultural data can be leveraged with the help of advanced computer techniques in order to derive optimal meaning out of them. In the best-case scenario optimizations can be executed wile treating the environment respectfully. The new approach implies farmers must act as supervisors of their crops, rather conventionally as laborers for the avoidance of repetitive, labour-demanding field tasks. For entering a modern agronomical framework, data will be the key for uniting concepts with on-field applications.

In my opinion all further effort should be invested towards the integration of smart farming practices in order to gather more evidence for creating case studies which approve the efficiency of smart farming. Young, ongoing farmers should be introduced to the concepts of data-driven farming approaches with subsequently data-sharing, rather than convincing existing incumbent farmers afterwards, in order for fostering the data-pool for retrieving more knowledge of farming practices for guaranteeing the food security for the next generations. Agricultural management systems will be able to handle the data in such a way, that the results are tailored and customized for providing solutions to each farm.

The author, Eduard Koch, declares no conflict of interests through the course of the thesis.

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