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Digital Transformation in Agriculture and the Role of Decision Support Systems

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1 Introduction

„*Digital technologies have the potential to revolutionize agriculture by helping farmers work more precisely, efficiently and sustainably.*" This is the first sentence of the EU web page on agriculture in the category of research and innovation (1.).

We believe that this widespread expectation is unjustified and would like to demonstrate this by comparing the value chain in industry and agriculture.

Digital transformation of agriculture raises high hopes and is seen as one of the key factors in developing a modern agriculture. Some, like Khanna (Khanna et al. 2021), see it even as "Imperative for sustainable agricultural production". The EIP-Agri site lists nearly 200 projects that deal with one or the other aspect of digital transformation. Google scholar lists 28.000 publications for the keyword "Digital Transformation in agriculture" in 2021. It seems every field of agriculture will be affected by digital transformation:

1. mechanization
2. work force organization
3. animal and plant health
4. production
5. stock management
6. distribution logistics
7. marketing

A bunch of new technologies is at hand to support or change each of these fields: the most recent field is the "Internet of Things", a domain that in itself comprises several new technologies like cheaper and better sensors, low-energy radio transmission, and communication protocols for efficient data distribution. But not only new technologies shape the digital change in agriculture. There is also a considerable development in "classical" IT, like better farm management systems, open data strategies from governmental bodies, cheaper hardware and so on. On the other hand, even recent studies show a relatively limited use of digital technologies in agriculture (Gabriel 2020). Many think the problem is the lack of business efficiency of digital products (e.g. Gandorfer 2017). We would like to point out, however, that digital value creation in agriculture is in principle significantly lower than in industry.

GEOsens has been part of that development for the last two decades. We are part of the VitiMeteo project since its start in 2001. Over the years we were involved in the development of farm management systems, monitoring, irrigation, sensor development, plant breeding, and of course various types of databases. We participate in research projects like AMLAB and Fungisens, led by the University of Hohenheim. Furthermore, we work in the field of environmental measurement technology, where we carry out geotechnical and hydraulic projects. We offer full service, from the sensor to the end customer.

2 The value creation chain

The digital transformation in industry is rightly called the 4th industrial revolution. It has changed every aspect of the production chain. Yet the basic pattern of the value creation chain has remained: **Raw materials** are processed in **factories** and converted into **goods**. These goods are sold to **customers**.

It seems that this simplified value creation chain is quite similar to that in viticulture or agriculture as a whole:

industry	**viticulture**
raw materials	vineyard
factory	field & cave
goods	wine
customers	customers

The value created is closely tied to the goods produced. We have to be careful not to confuse value and price: Price is determined by the relationship between supply and demand, value by the relationship between utility and production effort. So while the price can fall to zero, value cannot.

Due to the obvious analogy in the chain of value creation, it is widely assumed that the digital transformation will have the same positive effects for agriculture that it has already shown in industry.
We believe that this expectation is not realistic. In short, we believe that value creation through digital transformation in viticulture, and perhaps in agriculture in general, cannot even remotely approach that achieved in industry. We want to show why and how this affects decision support systems and the expectations attached to them with regard to the reduction of pesticides.

If we take a closer look we find significant differences between industry and agriculture. The most obvious is perhaps the production in closed vs. open systems. A factory can be seen as a closed system. The production capacity of a factory can be calculated. There are of course interfaces to the outside world, like the input of raw materials and the customer demand for products, but apart from these most other factors can be controlled and managed quite well.

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Wine production takes place in a much more open environment. The most prominent factors here are weather and plant diseases. These two alone make it difficult to determine the potential production in advance. They are the reason why decision support systems like VitiMeteo exist.

Another difference regarding the chain of value creation is its length: the chain is much longer in industry. This means that the product of one factory is very often the raw material of another. Value is added at every step. We will see later why this is of importance.

3 How digital transformation is changing production

As far as the digital transformation affects the production of goods, two main classes can be distinguished: Pure software products and hybrid products consisting of hardware and software.

Pure software products are software packages like Enterprise Resource Planning systems (ERP) or Customer Relation Management systems (CRM). In Industry the best known examples may be SAP and Salesforce. Similar software exists for agriculture, for examples 365FarmNet, Xfarm or FarmERP. This type of software supports and improves production through better organisation and planning, in other words: better efficiency and productivity.

Decision Support Systems (DSS) belong to the same class: well known in viticulture are for example DeciTrait, Horta, RIMpro or VitiMeteo. Of course weather forecast or irrigation systems belong to this class too. These systems address the special problems that arise in open production systems (weather and pests). They help mitigating risks and optimize plant protection and irrigation quite effectively, as already shown by Rossi et al.

Hybrid products are goods that consist of hardware and software. One might think of a smart watch. More specific for agriculture seems a field robot. In fact, every car and tractor today is a hybrid product; basically anything with four wheels has a traction control system, software-based engine management, GPS, digital interfaces and more.

Software adds value to these hybrid products, it makes them more useful. A good example is a the weather station: the good old thermometer from the last century has been digitally enhanced, and now it delivers values every few minutes by internet. While this is a value in itself, it has spawned a much bigger value than just a more accurate temperature record. The data are fed into irrigation systems, or plant disease models. Both would simply not exist if there was no digital weather station. This example shows quite well how big the value is that may be created by digitally enhanced or hybrid products. It is often far more than we imagine on the first glance.

So we conclude here that pure software systems can increase and optimize productivity, but only hybrid products add new value by improving the product itself. Hybrid products can even spawn entire new product chains and thus multiply value creation.

4 The impact of digital transformation in agriculture andindustry

The impact of the digital transformation on the general economic situation has been well studied. Gherghina, E. 2021 shows a clear correlation between the DESI (Digital Economy and Society Index) and the GNP of EU countries. McKinsey 2019 estimates that digital transformation will increase global GDP by about $1 trillion per year (for the period 2018 to 2030). The same paper shows large differences between economic sectors.

Calvino 2018 gives a taxonomy of digital intensity by sector, based on data from 2013-2015, with agriculture in the lowest quantile or zero in all sectors. The OECD Economic Outlook 2019 shows that low digital intensity sectors show an overall decline in productivity from 2009 to 2016.

Battati, C. et al. 2020 examined 12 European countries and the US. They distinguish between high, medium and low digital intensity industrial sectors and examine the contribution of each sector to productivity growth in relation to the integration of the sectors into the global value chain. They find that productivity gains are higher for medium and high digital intensity sectors, especially if they are well integrated into the global value chain. This supports our view that the length of the production chain multiplies the value created by digital transformation.

5 The reasons for low digital intensity in agriculture

There is little research on the specific reasons for above observations. We think that the reasons are structural and cannot be overcome easily:

ERP and CRM systems have produced high efficiency gains for industrial production and sales. At least for ERP systems, this has been possible due to the fact that production takes place in closed systems. They offer the conditions under which planning can be very effective.
Open systems like viticulture do not offer optimal conditions for planning tools. Planning can be annihilated overnight by the influence weather or pests. Of course the planning can be redone easier with good software, but the additional effort remains and lowers the efficiency gain. The best effects are probably realized in the cave, where conditions are more controlled.

But the really bad news is that in agriculture there are no digitally enhanced products. There is no “digital wine”, no “digital tomato” or “digital bread”. And our phantasy is not vivid enough to imagine any kind of digitised food in the future. This is a crucial point: the main driver of value creation through software simply does not exist in agriculture.
So gain in efficiency is somewhat lower and added value through hybrid products is non-existent. This alone shows clear enough that agriculture in general and especially

viticulture cannot expect to benefit from digital transformation as much as industry. But there is an additional factor to make it worse. Food in general and especially wine has much shorter production chains. An industrial production chain is much longer than in food production, and more of a network. And value is added to each link in the value chain. The short value chain of agriculture increases the disadvantage that already exists in the digital transformation.

6 How Decision Support Systems contribute to value creation

The contribution of DSS to value creation is very specific. One might assume that the product of a DSS is the advice it gives, i.e. the information it offers. If this was the case the advice had a value of its own. But information never is value in itself. The value of information lies in its relevance or usefulness. Again: we need to distinguish between value and price. Many scientific publications on the issue of "value of information" from Howard, R.A., 1966 to Borek et al. 2013 fail to make this distinction. They mistake price for value. But price is just a volatile form of measure for value. Here we use the term value to refer to the effort put into production. In that sense, the value of the information generated by DSS is relatively low.

The biggest part of the value we talk about is created by the action taken as a consequence of the information. In other words: it is not the DSS that creates value, but the winegrower.

In the case of a plant disease model the action may be:
1. go spray
2. do not go spray.

When the DSS recommends spraying, this helps protect the grower's crop. The value is in preventing losses, the benefit is directly to the winegrower.
When the advice is not to treat, this helps protect the environment. The value is to prevent losses in soil, water and biosphere quality. This value is indirect; most of it benefits the public rather than the winegrower.

So the utility of a DSS is partly directly for its users, partly for the public.

7 Wrong expectations

Now that we see who benefits, we might ask who should pay for it. This is a political question. We might look again at the historic development of industry: Industry caused severe pollution throughout Europe in the last century. As reaction the legislation was adapted step by step to force the industry to stop, to protect public goods like water, soil and air from degradation. Some prevention measures were paid for or supported with public money. However, the greater part of the necessary investment was provided by industry. The process of change towards a reasonably environmentally friendly industrial production began in the 1980s and continues until today. In the same period, digital transformation has enabled industry to increase its productivity enormously and create new hybrid products. This has led to a great increase in value, which has, among other things, paid for the costs of environmentally friendly production methods.

The situation in agriculture seems to be comparable: there is a big public pressure to reduce the use of pesticides and potentially environmentally harmful products. There seems to be a hope that digital transformation in agriculture will boost the productivity and thus generate a lot of added value, like industry did before. It is expected that these values can fund the desired ecological protection measures.

This creates a difficult situation for DSS in viticulture. Apparently, the assumption in politics and society is that it is enough to change the laws. Then the market will provide the necessary products and strategies for more environmental protection. Thanks to digital transformation, producers will achieve the necessary productivity gains to be able to pay for it.
We have tried to show above why this expectation might be wrong and why agriculture is nowhere near as likely to benefit from digital transformation as industry.

8 Consequences

There are two possible consequences of this misconception:
1. DSS and other environmental protection measures cannot be adequately financed and therefore cannot achieve the desired effects.
2. The cost of agricultural products increases. As a result, environmental regulations can become a negative competitive factor, ultimately leading to an exodus of production.

Neither of these options seems desirable. We believe therefore that it is essential to develop new strategies to finance and achieve the desired environmental protection goals. The digital transformation will not be able to produce the necessary productivity gains.

9 Conclusions

If we follow the chain of value creation, we see that digitalisation for agriculture is far from being able to achieve the same value creation as in industry.
This raises the question of whether and how extensive digitisation can be financed. The digitalisation of internal can farm processes can lead to increasing efficiency and thus perhaps be funded.
But digital improvements that essentially benefit environmental protection create value that cannot be directly monetised by the winegrower or farmer. They can therefore not be refinanced from internal yield increases.

We therefore warn against expecting too much from the digitalisation of agriculture. In particular, we consider it necessary that costs incurred in the public interest, such as those for DSS, are compensated or at least supported by the public.

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