Chapter

Smart-Field of the Farm, First Relevant Link of Transparent Path of Grapes in the Farm to Fork Value Chain: A Revue

Constantin Vîlcu, Steve Vanlanduit, Resul Kara, Aurora Ranca and Mohamed Bourouah

Abstract

Data-based farming facilitates the zonal management (Smart-FIELD) in the smart farm (SF) vineyards. The classic SCADA for data acquisition and processing system, used especially in rapid industrial processes, can also be adapted for the slow processes (during a vegetation period) of horticultural crops (including the vineyards). The Smart-SCADA core software activities will develop through AI modules the CPS technique for integrating IoT devices with operational applicability in vineyards SF. The Web Smart-SCADA core interconnection with the European platforms in use (UTOPIA, ATLAS, DEMETER, PANTHEON, SmartAgriHubs, ...) will add value in the transparency of the traceability of the F2F value chain of grapes.

Keywords: precision agriculture, multispectral monitoring of crops, IoT in vineyard smart farming, toward zero pollution in the farming environment, smart SCADA core in vineyards

1. Introduction

A little while ago, the European Green Deal (EGD) established the Farm to Fork Strategy for Next Generation Europe (NGE) in the agricultural field (R-D & Innovation, management of farms and the smart operations in real farming environment). Long ago, much ink flowed on paper for industrial development and the effort to move agriculture to a higher level. Now we have agriculture-4.0, where the analog pen has turned into a digital tool. We can write in machine code, thanks to the ICT technology, on the virtual paper from the SSD hard drive of the PC for the variable rate actuation of the execution elements in the processes of horticultural crops (vineyard inclusive).

Data-based farming will represent the agriculture of the future. In this sense, ICT systems have a crucial role in data acquisition (metadata), analysis and decision support (DSS), action with variable rate of actuation (VRA) in crops processes, and promotion of agri-food products through the IoT technique, [1]. The hardware-software integration of these systems in any agricultural sector allows the farmer to obtain higher harvests with reduced expenses, i.e., a profitable ROI (the first point of view - that of the farmer). The second point of view is at the other end of the F2F value chain - end user, and represents the needs of the end consumer to have quality (healthy) and cheap products. Between these two extreme points of view, the TZP-UTOPIA-F2F concept seeks an optimal path and conforms to the Farm to Fork Strategy. The paper addresses the horticultural sector of the culture processes in open spaces and focuses the activities of work in the vineyards for SF digitization.

As rationale for SMFs that represent a significant part of EU horticultural landscape, the paper approaches vineyard farms regarding F2F Strategy. The digital transformation of this agricultural sector (through data-driven farming) is crucial for addressing global issues related to climate change and implicitly in the sustainability of F2F agri-food value chain. As method, the TZP-UTOPIA-F2F concept will develop a smart-SCADA core system adapted to the needs of horticultural SMFs and implement the software modules that enable a scalable, easy and economically feasible approach of the management of vineyards farms in the digital context of extreme climate change constraints.

Smart-FIELD of the farm, is the first relevant link at the potential applications of TZP-UTOPIA-F2F concept and will combine new ICT technical solutions with innovative learning systems to achieve the adoption of digital technology in vineyard farms. As impact and potential benefits, the TZP-UTOPIA-F2F works make an in-depth analysis of the socio-economic issues of precision farming in vineyards, an assessment of the return on investment and the development of sustainable business models, will provide new and innovative possibilities for vineyards SF to produce the necessary and healthy food in the context of the F2F Strategy.

2. Edge-activities in operational FIELD of vineyard Smart Farm

2.1 Why, Smart-FIELD in vineyards?

In order to obtain quality and profitable products, farmers from vineyards must respect and even permanently adapt the technological links of the culture system to climatic constraints. Their cost price must cover all the necessary products (fertilizers, pesticides, fuels, etc.) and, at the same time, be competitive on a sufficiently saturated market, such as the European one. Farmers are currently facing two major constraints, the high price of inputs and the demand of consumers to find cheap and healthy products on the market. In this context, we meet the demands of consumers by ensuring a diminishing of the inputs and a traceability system of wine products from the farm, to finished products such as grapes intended for fresh consumption, fresh must or preserved by pasteurization and wines of different types and levels of quality. The system can come to the aid of certification bodies, for example ecological certification, or those that verify and attest the origin and quality of wines. Through the various signs provided to manufacturers for application on labels (logos, holograms, QR codes), the degree of consumer information increases considerably (MUR) [2, 3].

2.2 How, do we operate in the vineyard?

Farmers are heavily investing in digital technologies to improve their productivity and to safeguard their harvest from losses due to drought, pests, etc. Multispectral imaging systems installed on mobile platforms (like mobile robots, drones) are a valuable tool to reach this goal. Unfortunately, the imaging systems and platforms that are currently available are expensive, and difficult to use (by farmers without expertise in computer programming). The InViLab research group of the University of Antwerp will develop a low-cost multispectral vision system (consisting of industrial cameras and image processing units integrated in a compact housing). State-of-the-art machine learning algorithms will be developed to monitor the growth and health of the vineyards (both at plant and at field level). The algorithms will be deployed on edge platforms to realize real-time performance. In the work the methodology developed by InViLab is applied to vineyards, even though the applicability of the framework is much wider: seaweed monitoring and monitoring of vertical greenery systems applied to buildings (UAB) [3, 4].

2.3 How do we have, F2F traceability?

Improvements in IoT devices have been going on for many years. Especially in recent years, with the use of IoT in the field of farming, healthier, more efficient and traceable products have been grown. By evaluating the data collected from the environment and products that are grown by various methods, the way to obtain more perfect products has been opened. Similarly, in the light of the data obtained by using the surrounding sensors, it is possible to intervene immediately in adverse situations that will affect the development of the product. In this study, both product-related data and data about environmental conditions will be collected quickly from various sensors located in a wide area of agricultural land. Thanks to the advanced IoT network, all data will be collected in the central communication unit and situations that require urgent intervention will be decided. Necessary actions can be taken in emergencies. The data collected from the environment will be sent to the cloud system for processing together with the actions taken and all other data. In the next phases, the feedback from the customers will also be recorded in this system, and thus the products will be tracked from the farm to the table. In addition, the farmers will have the opportunity to monitor their products grown in the field and in the F2F value chain (DU), [3, 5].

2.4 What is needed to solve the problem?

An ICT system durable solves the problem by digitizing the SF vineyard. For data-driven farming is needed the integration of a Web SCADA (data acquisition and processing system). Smart-SCADA core software activities will develop through AI modules the CPS technique for integrating IoT devices with operational applicability in SF vineyards. The interconnection with the UTOPIA platform will add value to the TZP-UTOPIA-F2F concept. The graphic transformation for mathematical modeling of the F2F process is presented in **Figure 1**, from organizational chart 1. (a) – F2F agri-food chain management for grapes products, to the graph 1. (b) – Graphic diagram of the F2F agri-food value chain: 1-Farm, 2-Fork, 3-Crop storage, 4-Food processing, 5-Distributor transporter, 6-Agri-food market, 7-Food health safety (FHS), 8-web

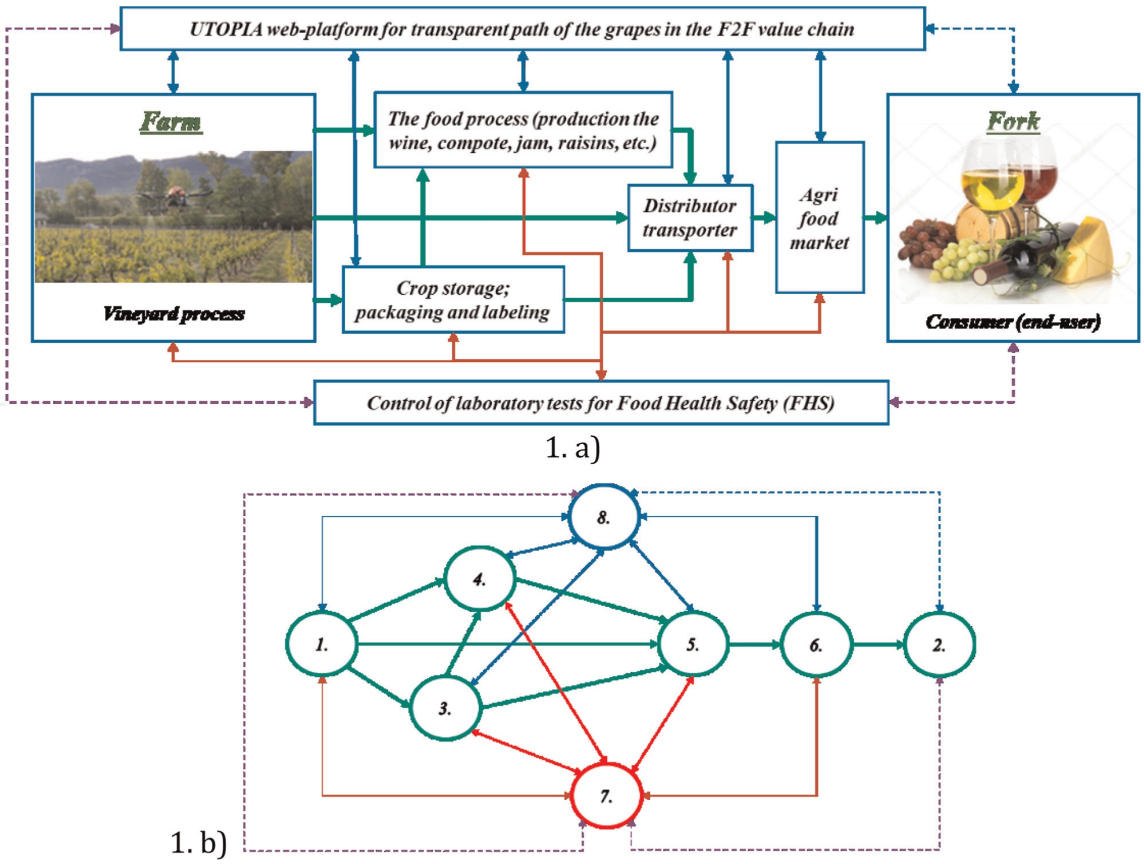

Figure 1.
Transparent traceability of agri-food products from Farm to end-user.

platform UTOPIA, which is the basis of Fuzzy neural processing in the software module integrated of TZP-UTOPIA-F2F concept, (INMA), [6–8].

3. Materials and methods

3.1 Excellence

The World is currently facing several challenges, [9]:

- At current growth rate, by 2050 there should be over 9.5 billion people to be nourished;
- Chemical based mass-agriculture, despite higher short-term yields, negatively impacts food safety and will lead to soil impoverishment on the long-term and reduced yields;
- The overall Farm to Fork value chain produces 25% of worldwide emissions directly contributing to climate change crisis;
- 75% of F2F emissions are located in the agricultural environment.

The paper has chosen to address of TZP-UTOPIA-F2F concept for Agri-food systems enabled by interconnected digital technologies that are more transparent to

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consumers, farmers and other stakeholders along the agri-food value chain, as a strong collaborative engagement to impact positive for a healthy life.

From the multiple sectors of activity of Agriculture presented in the tree graph in **Figure 2**, the branch was chosen: Agriculture → Crop farming → Horticulture → Olericulture. Why horticulture? Horticulture represents, through its activities in open and closed spaces (greenhouses), the "art" of vegetable crops in agriculture. Vineyards and fruit farms cover an extensive area of Europe and the automation of process crops in these areas is experiencing a high development. The TZP-UTOPIA-F2F concept is for data-processing in vineyard crops in order to promote the grapes product in the F2F value chain.

Ultimately, TZP-UTOPIA-F2F concept has been conceived to create value for farmers and consumers through the Farm to Fork value chain, while restoring value to the Natural Capital value chain (see **Figure 3**). The farm is the main link in the F2F value chain, obtaining organic food products (e.g., grapes) must be promoted transparently so that end-users know that the consumed product is fresh and healthy.

By assessing all indicators related to the use of intrants, such as pesticides and fertilizers, as well as monitoring the state of nutrients, Web Smart-SCADA core

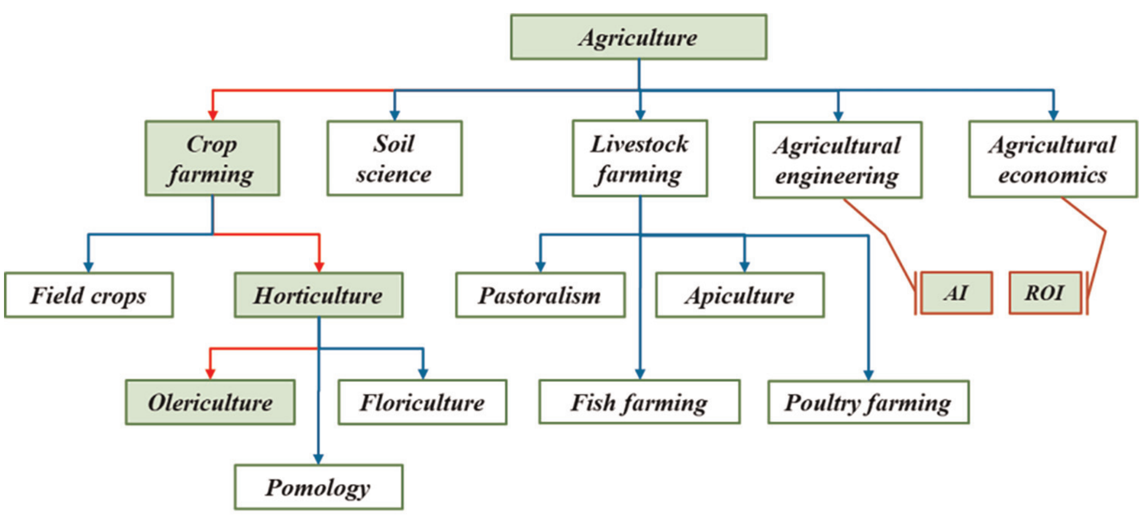

Figure 2.
Summary of branches of agriculture.

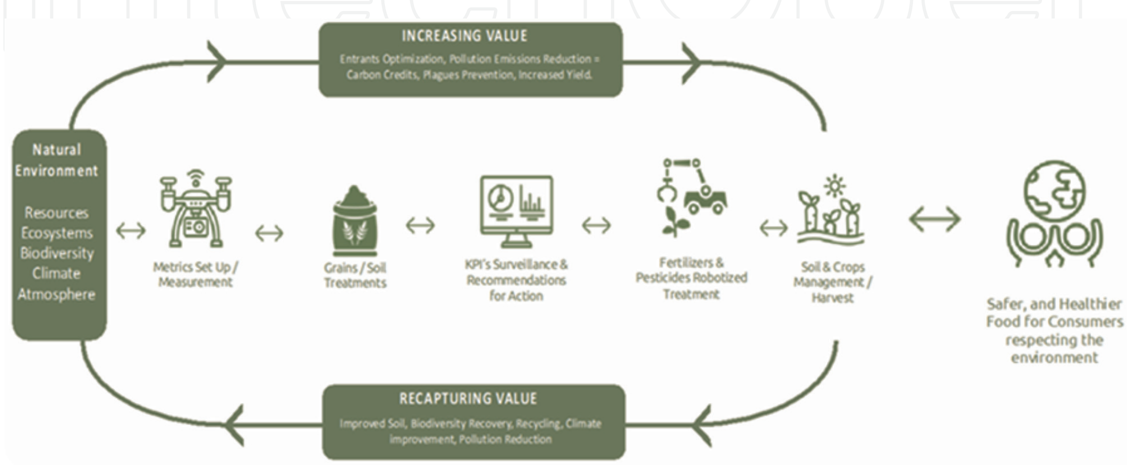

Figure 3.
Method of restoring the value to Natural Capital value chain.

through AI software modules will provide farmers with automatized call-to-action recommendations to farmers. Once farmer validates call-to-action SF will automatically provide point-specific agriculture surgical treatments (watering and other intrants) with newly developed operating plans compliant pesticides, fertilizers and other nutrients, reducing water pollution, polluting emissions and intrants waste across the cycle of farming production. This will have a positive impact on the health of the agri-food products produced (e.g., grapes).

3.2 The overall concept and progress beyond the state-of-the-art

Regardless of the field of the agricultural environment (plant or animal kingdom), data-based agriculture requires data acquisition systems, IoT sensors and devices, IT technique, or in a word CPS that allows the storage of monitored data in large databases, necessary for analysis further for an intelligent management of the agricultural process.

The aim of the work is to digitize the vineyards by implementing the ICT technology in Smart Farm, consisting in Web Smart-SCADA core integration and the scalable software packages for easy methods of learning sustainable farm management toward zero pollution. Today, precision farming or agriculture-4.0 is no longer a new concept in farming operations management using UAV drones (for measurement, aerial observation and response to crop variability) and/or GRS robots (for resource efficiency even in cases where they are limited). The use of these MAS systems in a unitary hard-software framework of TZP-UTOPIA-F2F concept, leads through the F2F strategy, to the achievement of the following targets: (i) obtaining high quality farming crops; (ii) ROI economic profit optimization; (iii) integrated environmental protection to TZP, (iv) Cloud connection with the UTOPIA platform to allow full visibility of the health status of grapes in F2F value chain for a complete and reliable traceability of agri-food products to the end user.

The TZP-UTOPIA-F2F concept has a high degree of novelty through Web smart-SCADA core that unifies software relevant preliminary results from agriculture-4.0 for advanced vineyard SFs management. This paper, in relation to the current state of the art technology, facilitates the transition to agriculture-5.0 or agriculture based on management of large databases in cloud (metadata). After the Industrial Revolution, especially since the advent of mechanization and during the Green Revolution, farmers and their machines worked together effectively to cultivate crops with a tendency to digitize agriculture.

A new approach driven by digital technology implies that growers need to act as supervisors of their crops rather than as workers, thus avoiding repetitive, demanding and tiring tasks in the field. In this modern agricultural setting, agricultural databases are key, and the information-based management cycle provides the practical approach that combines the concept of Smart-FIELD with agricultural tasks. Agriculture based on large databases on crops and the farming environment, with the help of MAS systems that incorporate state-of-the-art AI techniques, lays the foundations for sustainable farming of the future (agriculture-5.0), [3].

3.3 Ambition of works

Unmanned Aerial Vehicles (UAV) and Ground Robotic Systems GRS, as collaborative Multi-Agent Systems (MAS), make a crucial contribution to improving

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precision farming by controlling the TZP global index for sustainable agriculture. Monitoring the Inputs in agricultural process and the state of crops vegetation are essential in management of SF. The processing of data recorded for the monitored crops influences managerial decisions and implicitly the ROI indicator of vineyard farm.

The components of the abiotic environment (air, water, soil) are vital as inputs together with the planting material for a sustainable SF. The current trend is to make smart farming by automatically controlling inputs and outputs. Supervisory control and data acquisition of agricultural processes involves the introduction of high-performance technologies to streamline the farming process and ensure control of production in ecological conditions. All farmers try to get as much agricultural production as possible at the lowest cost.

To this end, the paper proposes the creation of a Smart SCADA core for vineyard precision farms with an integrated package of Smart-FIELD software modules for easy learning of the new generation of farmers for the management of SF. The TZP-UTOPIA-F2F model will be physically materialized through a dedicated Web SCADA core system by parameterization to any SFs that integrates it.

The human operator in the farm control center is continuously interconnected with MAS systems and on-site sensors to control the process and pollution of the agricultural environment. Thus, TZP-UTOPIA-F2F allows real-time assessment of crops and the agricultural environment without the need to move the human operator. The main target of the works is therefore the digital creation and implementation of modular software packages that allow a scalable and easy approach to the management of vineyard farms in the sustainable context of TZP. It's shown in **Figure 4** the automation process diagram for vineyard farms in the new TZP-UTOPIA-F2F concept of F2F strategy, [3, 6].

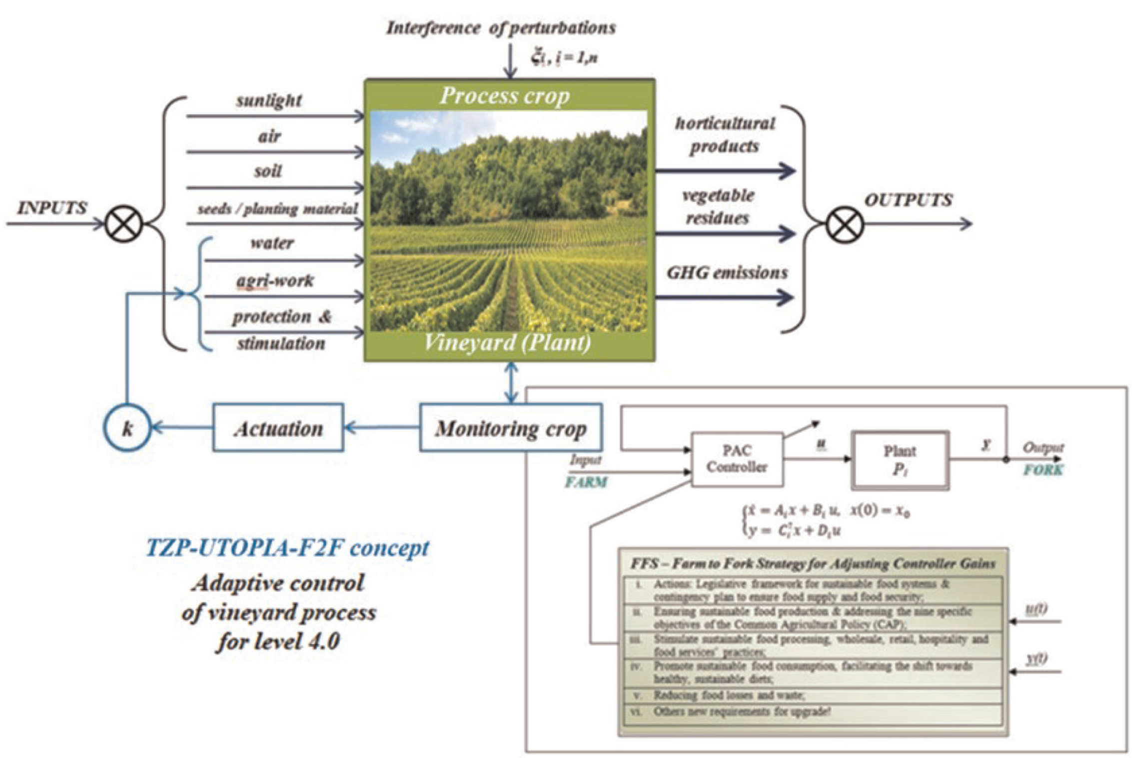

Figure 4.
Automation process for vineyards farms in the new TZP-UTOPIA-F2F concept of the F2F strategy.

3.4 List of parameters for Smart-SCADA core

The hard- and software implementation of the Web Smart-SCADA core in the SF vineyard, requires the existence of a minimum equipment's and IoT devices to ensure

Integrated equipment in smart farming (vineyards)	**#**	***List of monitored parameters for TZP-UTOPIA-F2F concept***			
		Abiotic component		***Symbol***	***Name***
 [10]: air sensors*	1	***Air***	General indicators	T_a	Air temperature
	2			H_a	Air humidity
	3			p_a	Barometric pressure
	4			*Ws*	Wind speed
	5			*Wd*	Wind direction
	6		Special indicators	*TSI*	Solar irradiation (Sun intensity - lighting) [W/m^2]
	7			*CO*	Carbon monoxide
	8			CO_2	Carbon dioxide
	9		Critical indicators	*PM*	Dust particles (PM – particles matter)
	10			*FW*	Frost warning
	11			NO_x	NOx gases
 [11]: water sensors*	12	***Water***	General indicators	T_w	Water temperature
	13			*pH*	pH
	14			*DO*	Dissolved oxygen
	15			EC_w	Electrical conductivity
	16			*Wt*	Water turbidity
	17		Special indicators	Ra^*	Rain amount [l/m^2]
	18			Ri^*	Rain intensity [l/m^2/h]
	19			*ORP*	Oxygen reduction potential (Redox) [V]
	20		Critical indicators	P_{est}	Pesticides
	21			O_{rth}	Orthophosphates
	22			NO_3	Nitrate
 [12]: soil sensors*	23	***Soil***	General indicators	T_s^*	Soil temperature
	24			VWC^*	Soil moisture (volumetric water content in soil)
	25			EC_s	Soil electrical conductivity
	26		[13]: Special indicators	*N*	Azote (Nitrogen)
	27			*K*	Potassium, (Kalium)
	28			*Mg*	Magnesium
	29		Critical indicators	IW^*	Soil water tension (Irrometer Watermark measures moisture available for plants)
					...

Integrated equipment in smart farming (vineyards)	#	***List of monitored parameters for TZP-UTOPIA-F2F concept***			
		Abiotic component		***Symbol***	***Name***
 [14]: MAS* - remote sensing	30	***Crops***	Remote sensing - Satellite	*EVI*	Enhanced vegetation index
	31				...
	32		Remote sensing - Drones	*NDVI*	Normalized difference vegetation index
	33				...
	34		Remote sensing - GRS	*NDVI*	Normalized difference vegetation index
	35				...
 [15]: other* sensors	36	***Other***	General indicators	*LW**	Leaf wetness (Meter Group PHYTOS 31)
	37			pH_v	pH
	38			SO_2	sulfur dioxide
	39			*Rs*	reducing sugars
	40		Special indicators	*YAN*	Yeast assimilable nitrogen
	41			*Tsc*	tartrate stability by conductivity
	42			*Bt*	bentonite
	43		Critical indicators	*Sc*	sugar content
	44				...
	45	...	...		...

See Reference.

Table 1.
List of the usual parameters monitored in the SF vineyards.

monitoring the list of parameters in **Table 1**. The multitude of sensors in the field must ensure a minimal list of monitored parameters of the culture through the processing of which in the DSS software module results in those VRA operations when the situation in the field requires it.

3.5 Originality of the proposed approach of article

The originality of the approach proposed in this paper is the definition and calculation of the quality global indicator TZP of the agricultural environment toward zero-pollution within the processes of agricultural crops as a basic principle of precision farming.

The TZP principle – Toward Zero Pollution is the principle of supervisory control of inputs (air-water-soil) and outputs in a horticultural process to strive for "zero-pollution" through advanced management of inputs/outputs using MAS systems. In the following, a combined global indicator function is defined, which provides an index of the degree of pollution of the three abiotic components of the air-water-soil agricultural environment. This is represented by a matrix function with the index "TZP" and (f_q) variables, randomly determined at the t time throughout the T period of a horticultural process:

$$\left[F_{TZP}\left(f_q,\ t\right)\right] \tag{1}$$

Only the monitored values of the polluting parameters of the abiotic environment will be taken into account. Carrying out the successive replacements according to the stages described in the paper [12], for a work variant adapted to the horticultural process in the vineyard, the following TZP global indicator function is obtained:

$$\left[F_{TZP}\left(f_q,\ t\right)\right] = \left\| \begin{matrix} \left(\prod_{i=1}^{l} x_i(t)\right)^{\frac{1}{l}} & 0 & 0 \\ 0 & \frac{1}{m} * \sum_{j=1}^{m} y_j(t) & 0 \\ 0 & 0 & \frac{\sum_{k=1}^{n} \omega_k \bullet z_k(t)}{\sum_{k=1}^{n} \omega_k} \end{matrix} \right\| \tag{2}$$

The attached determinant to the global indicator function $[F_{TZP}]$ take values in the [0,1] range. A subunit value in the vicinity of “0 + 0” indicates that process in the vineyard is environmentally friendly.

$$det.\left[F_{TZP}\left(f_q,\ t\right)\right] = \left|F_{TZP}\left(f_q,\ t\right)\right| \overset{t=T}{\to} 0 \tag{3}$$

where: $t \in (t_0, T)$, T being the period of a vineyard production process (grapes maturity period).

The SCADA software program in LabView code automatically creates the color graphic representation shown in **Figure 5** required for product packaging labeling and grapes promotion in the F2F value chain [3].

3.6 Minimum devices and mandatory equipment for Smart-SCADA core in vineyard SF

A complete list for equipping a pilot station as a smart vineyard farm is a complex problem because it depends on the following factors: economic-financial, geographical, climate, agrarian policy of the vineyard farm. It’s shown in **Figure 6** the specification of the first device necessary for monitoring the farming environment in vineyard SF. Mobile app for remote crop monitoring with Meteobot provide, [16]:

- Current and historical data from weather stations;
- Local weather forecast for 10 days;
- Agronomic indicators such as rain sum, temperature sum, etc.;
- Weather notification for frost, intensive rain, etc.

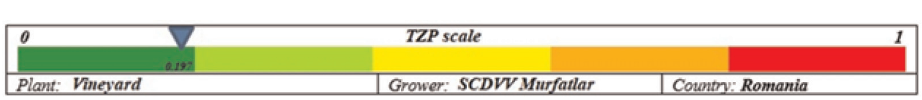

Figure 5.
Graphic representation of the TZP quality global indicator.

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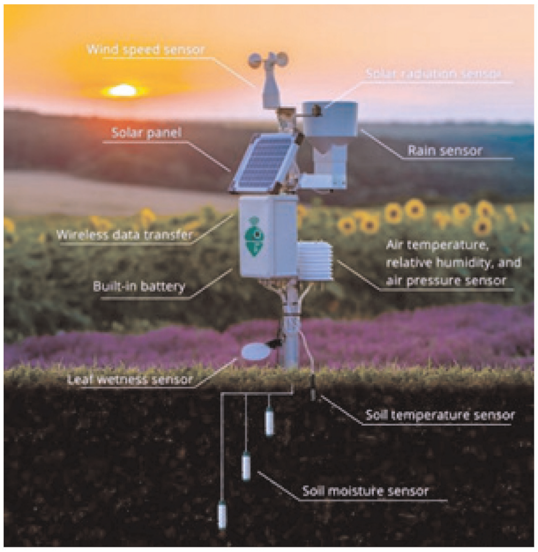

Data specification equipment.
Complete agrometeorological weather information:

- Rain;
- Wind;
- Soil moisture and soil temperature;
- Air temperature, air humidity and air pressure;
- Leaf wetness and solar radiation (options);
- Upgradable upon request;
- Weather history for each field.

Figure 6.
Agricultural farm weather station Meteobot®Pro model, [16].

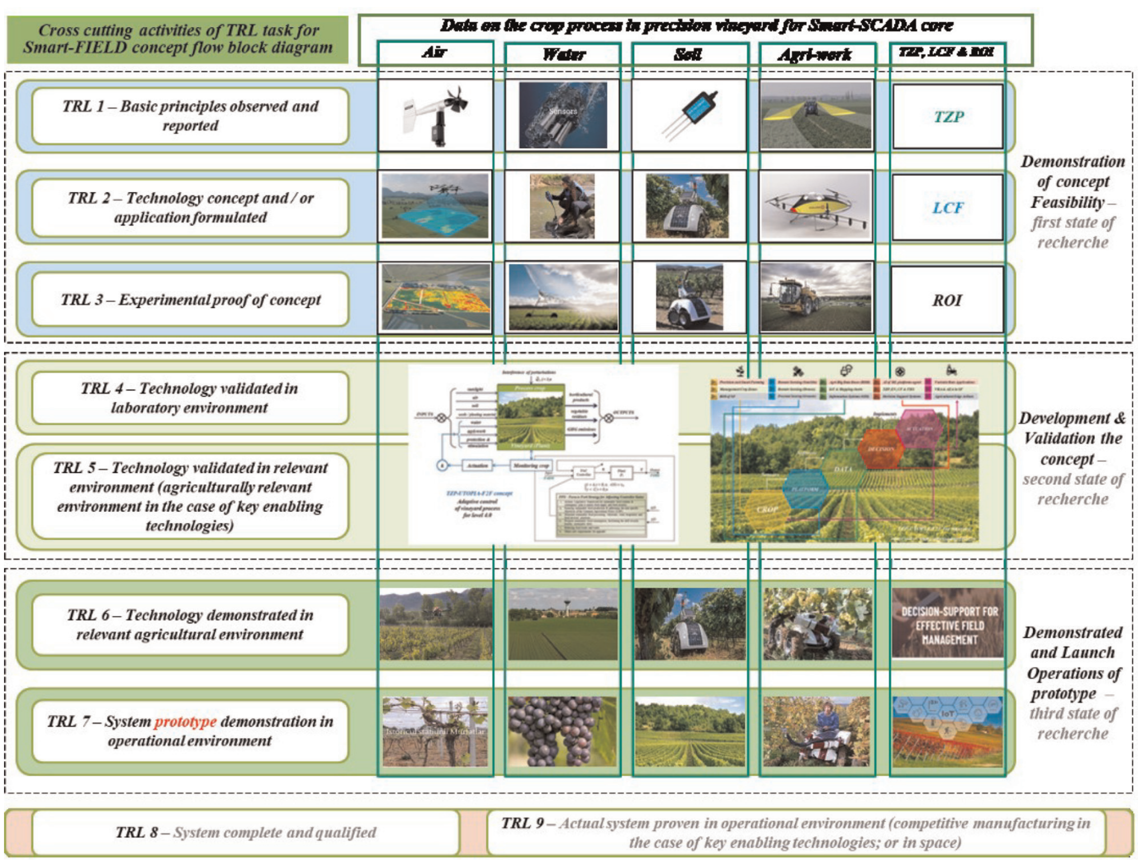

Figure 7.
Cross cutting activities of TRL tasks for the Smart-FIELD and flow to prototype.

3.7 Implementation the Smart FIELD to prototype level in vineyard SF

Realization of the TZP-UTOPIA-F2F concept brings an extra novelty through the hard- and software elements created for digitization of vineyards SF. Complete automation of farming processes in vineyard SFs through centralized digital management from the farm PC of UAVs, GRS (as MAS) and of execution elements (for plowing, arable land preparation, sowing, irrigation, protection, stimulation, harvesting, transport and storage), makes easier activity of the farm manager in making decisions regarding ROI. The cross-cutting activities for TRL tasks of Smart-FIELD within the TZP-UTOPIA-F2F concept are shown in **Figure** 7, [3].

4. Conclusion

The Smart-SCADA core model of TZP-UTOPIA-F2F concept to be developed and tested in real Pilot farm (MUR) as an easy method and **S**mart technique to **F**ostering **I**nnovativ**E** **L**earning for **D**igital agriculture-4.0 (Smart-FIELD) is built on four pillars as basic principles: (i) monitoring the NDVI & EVI vegetation index of crop; (ii) TZP - toward zero pollution of crops process; (iii) ROI - Return on Investment, (iv) Transparent traceability of agri-food products between the F2F for the end user and other stakeholders. The basic Smart-SCADA package and AI scalable software modules are based on deterministic mathematical models that define the stated principles.

Smart-FIELD – Easy techniques to promote innovative learning for digital agriculture toward Zero-Pollution, will be addressed through applied research in the MUR Case Study within the TZP-UTOPIA-F2F project, as integrated smart actions in the SF vineyard. Transparent traceability of agri-food products between Farm to Fork for the end user and other stakeholders will be guaranteed for grapes, through the veracity of data monitored and transmitted from the smart vineyard. Web Smart-SCADA core

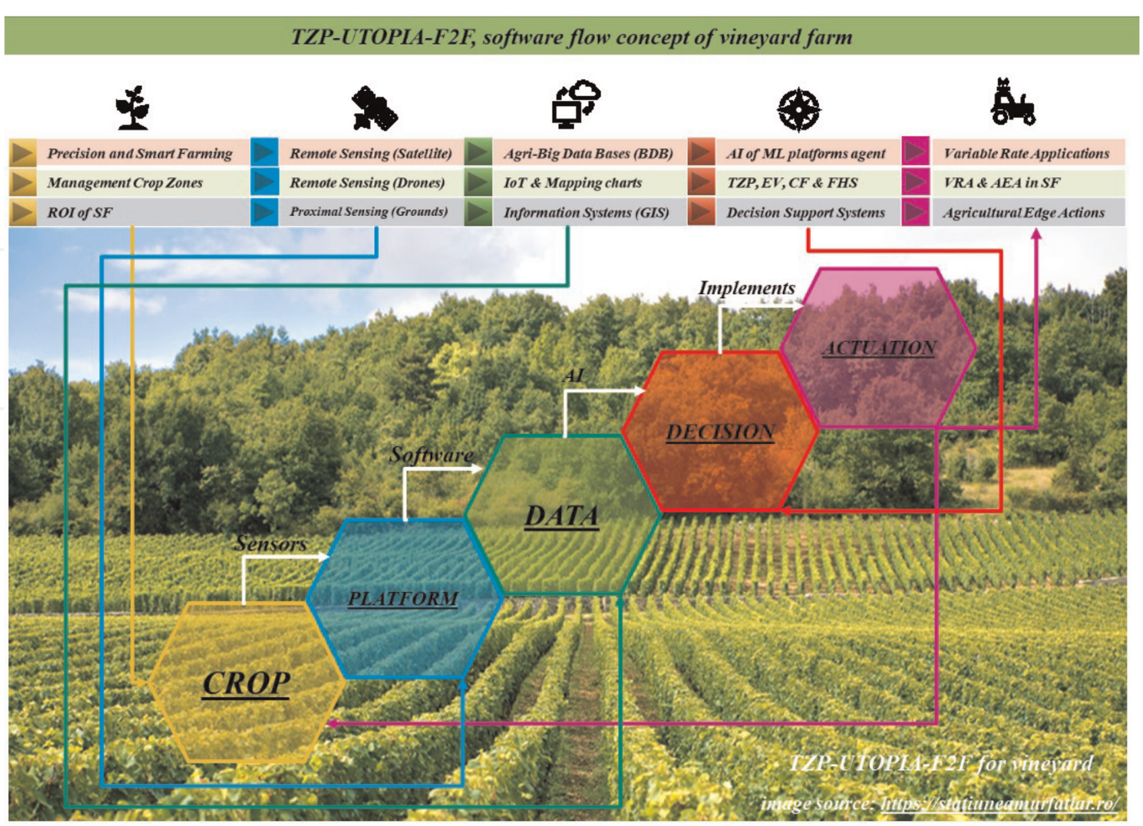

Figure 8.
Smart-SCADA core architecture of flow process from CROP to VRA actuation for data transparency in F2F chain value.

software flow of TZP-UTOPIA-F2F concept for SF vineyard as future research directions in agriculture-5.0 is shown in **Figure 8**.

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Conflict of interest

"The authors of this paper declare no conflict of interest."

Acronyms and Abbreviations

AI	Artificial Intelligence
LCF	Low Carbon Footprint
CPS	Cyber-Physical System
MAS	Multi Agent Systems
DSS	Decision Support System
NIR	Near InfraRed
EV	Edge Vision
NDVI	Normalized Difference
EVI	Enhanced Vegetation Index
FHS	Food Health Safety
ROI	Return on Investment
F2F	Farm to Fork
SCADA	Supervisory Control and Data
GPS	Global Positioning System Acquisition
GRS	Ground Robotics System
SF	Smart Farm
IoT	Internet of Things
SMF	Small and Medium Farm
SRS	Smart Robotic Systems
UAS	Unmanned Aerial Systems
TZP	Toward Zero-Pollution
UAV	Unmanned Aerial Vehicles
TZP-UTOPIA-F2F	Toward Zero-Pollution concept in Farm to Fork
VRA	Variable Rate Application

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