PRINCIPLES OF INTEGRATION THE AGRI-DRONES IN AGRICULTURAL PRODUCTION ENVIRONMENTS. NEW CONCEPTS TOWARDS AGRICULTURE-5.0
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PRINCIPII DE INTEGRARE A AGRI-DRONELOR ÎN MEDIILE DE PRODUCȚIE AGRICOLĂ. NOI CONCEPTE SPRE AGRICULTURA-5.0

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REZUMAT

Sistemele aeriene fără pilot (UAS) au o contribuție crucială la dezvoltarea agriculturii de precizie (PA). Dronele agricole sau agri-dronele fac rapid trecerea de la sistemul militar (UAVs) la aplicațiile domestice din PA, în scopul acordării sprijinului necesar fermierilor pentru supravegherea culturilor întinse și / sau în efectuarea operațiunilor de protecție sau stimulare a plantelor. Acest salt de nivel revoluționar contribuie la economii considerabile ale fermierului, precum și la revoluționarea agriculturii tradiționale spre agricultura inteligentă sau PA. Deciziile manageriale bazate pe cele trei principii prezentate în lucrare (EVI – Enhanced Vegetation Index, ZP – Zero Pollution şi ROI – Return on Investment) sunt mai ușor de luat prin abordarea condusă de tehnologia digitală. Ciclul de management bazat pe informații pune bazele unei agriculturi durabile a viitorului (agricultura-5.0)

ABSTRACT

Unmanned aerial systems (UAS) have a crucial contribution to the development of precision agriculture (PA). Agricultural drones or agri-drones make the rapid transition from the military system (UAVs) to domestic applications in the PA, in order to provide the necessary support to farmers for the surveillance of large crops and / or in carrying out operations to protect or stimulate crops. This revolutionary leap contributes to the considerable savings of the farmer, as well as to the revolution of traditional agriculture towards intelligent agriculture or PA. Managerial decisions based on the three principles presented in the paper (EVI - Enhanced Vegetation Index, ZP - Zero Pollution and ROI - Return on Investment) are easier to make through the approach driven by digital technology. The information-based management cycle lays foundations for sustainable PA of the future (agriculture-5.0).

INTRODUCTION

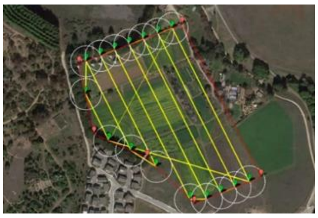
Agricultural production environments indicated for use of agri-drones

The payload and flight autonomy are two essential features of UAVs that today limit the use of drones as UAS operational platforms in agriculture, especially for large crops. However, monitoring operations (technical-scientific investigation, cartographic scanning, spectral maps of crops, etc.), phytosanitary treatment operations by spraying and / or emergency logistical transport in isolated or inaccessible areas, make agri-drones, the operational tools useful in many agricultural environments of production.

A recommended agricultural production environment for the use of agri-drones is the horticultural environment. Horticulture is the art of cultivating plants in gardens to produce food and medicinal ingredients or for comfort and ornamental purposes. So, it is an agricultural environment that deals with the cultivation of plants to improve their growth, yields, quality, nutritional value and their resistance to insects, diseases and environmental stresses. Unlike the agriculture of which it is a division, horticulture does not include the production of large-scale crops or animal husbandry. In addition, horticulture focuses on the use of small plots with a wide variety of mixed crops, while agriculture focuses on a single large primary crop at a time.

The horticultural environment must be an ecological environment for humanity. Organic farming has emerged as an alternative to the intensive, conventional (industrialized) practice of agriculture based on maximizing production by using inputs, energy-intensive production stimulators in large quantities, in order to continuously increase agricultural production for a population constantly growing. Regardless of the agricultural environment, organic farming promotes sustainable, diversified and balanced production systems, in order to prevent crop and environmental pollution. Interest in organic products and production is growing in the EU, [6].

The industrial agriculture system tends to be replaced in time by "organic farming" or "sustainable agriculture". In this context, PA appeared, as an effect largely caused by the agricultural services provided by the UAS and digitization platforms for a sustainable agriculture. It's shown in Fig. 1 and Fig. 2, agricultural environments in which the use of agri-drones has essential contributions in investment recovery (*ROI*), zero pollution (*ZP*) and advanced management of cloud-based agriculture (*AgroFlyData*). PA is an agricultural management concept based on observation, measurement and response to inter- and intra-field variability in crops. The purpose of the PA is to apply more efficiently the limited resources of a farm to achieve maximum yield.



a) automatic flight parameterization

b) giant spray drone (200 kg payload)

Fig. 1 - Operations in the horticultural environment: a) multispectral mapping; b) phytosanitary treatment, Link source: a)https://bestdroneforthejob.com/drone-buying-guides/agriculture-drone-buyers-guide/; b)https://www.volocopter.com/solutions/volodrone/

Due to its nature, the PA requires a lot of data for processing and to provide optimal managerial decisions in the operation of the farm. The main data types include: (i) geo-tagged images: visible and multi-spectral aerial images taken from the crop field at a priori defined time intervals (data provided by UAS agri-drones); (ii) performance equipment: real-time feedback and logs provided by IoT devices and farm equipment sensors (data provided by seeders, distributors, tractors, combines, etc.); (iii) management data: crop yields and other data provided by agricultural operators. Complete testing of these innovative technologies is still at the demonstrator level (see Fig. 2).

a) small area vineyard

b) mountain vineyard

Fig. 2 - Phytosanitary treatments in the viticultural environment, operator AgroFly SA Switzerland

Link source: http://www.agrofly.aero/fr/

Overflight approval in the use of agri-drones

All operations of UAS platforms in the agricultural environment will be carried out in accordance with the provisions of Regulation (EU) no. 2019/947. From the point of view of the authorization of flight activities, taking into account the normative acts issued the remote operator / pilot must comply with the provisions: (i) 14 of Law 21/2020 on the Air Code regarding the establishment of the take-off / landing point in case of flight involving unmanned aircraft on board; (ii) 13, para. (3) of Law 21/2020 on the Air Code regarding the altitude regime; (iii) 15, para. (2) and (3) of Law 21/2020 on the Air Code regarding the prohibition of flying over densely populated areas / gatherings or objectives belonging to structures in the national system of defence, public order or national security; (iv) the authorization procedure detailed in Government Decision no. 912/2010.

According to the legislation in force, all RPAS (Remotely Piloted Aircraft System) / UAV / UAS aircraft must be registered with the specific authorities. Thus, the AACR (Romanian Civil Aviation Authority) requires that any unmanned aircraft over 25 kg MTOW (Maximum Take Off Weight) be registered and registered by the operator. Each individual RPAS will be assigned a unique certificate registration code, an RFID (Radio Frequency Identification Device) and a unique registration number: YR-Dxxxx, where x is a digit from 0 to 9. At the same time, AACR also offers insurance against material damage that may occur as a result of an abnormal flight. Small drones, ~10 kg MTOW are classified as RPAS Utility category aircraft and are approved for operations and missions such as: Aerial photography; Leakage monitoring of industrial installations; Coastal erosion monitoring; Spectral maps vegetation crops; Research-development activities, [7].

The horticultural environment in the EU, for the use of agri-drones both in urban areas (urban agriculture) and in extra-urban areas (in-situ agriculture), requires overflight approval on human security. The agri-drone 4.0-MHRT model INMA shown in Fig. 3 has a high payload (66 daN) because it is intended mainly for spraying operations on phytosanitary treatment of crops. For a 99 [kg] MTOW, AUW (All Up Weight), the Y6-configured 4.0-MHRT multi-copter must be registered with the AACR before it can be put into service. Further details on both the drone registration procedure and the overflight approval for work operations in agri-drones use areas can be found in INMA PR#1, project code PN-III-P2-2.1-PED-2019- 4123.

Fig. 3 – YR-D1xx1 model 4.0-MHRT, operator INMA Bucharest RO

MATERIAL AND METHOD

Basic principles regarding the integration of agri-drones in precision agriculture

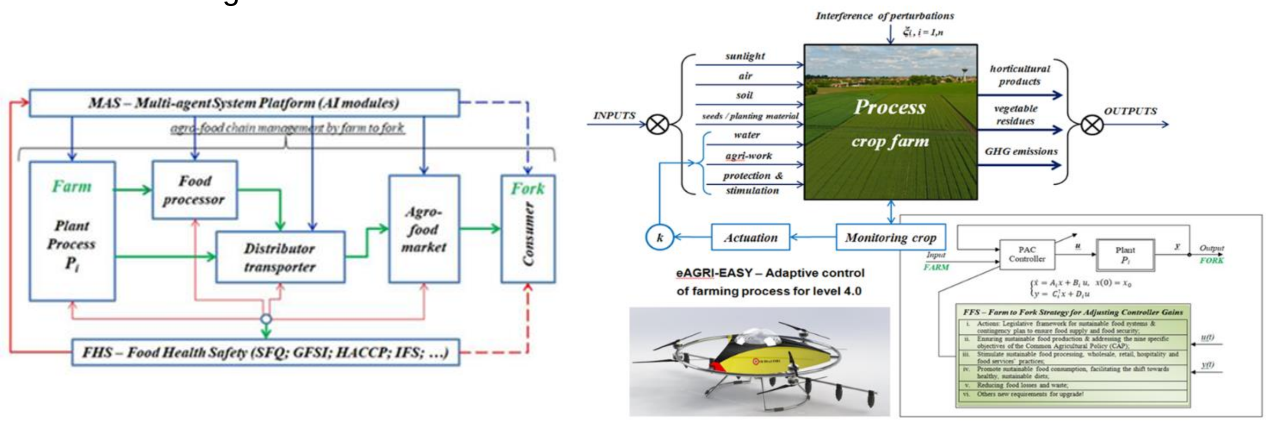
The basic principles or fundamental scientific elements in elementary physics are the basis for design of CAE (Computational Aided Engineering) of the UAS platform. We argue the statement with the following edifying examples: (i) The aerodynamics of the UAS of the mechanical structure of the agri-drone is governed by the Bernoulli Principle; (ii) The UAS inertial model for agri-drone dynamics is based on the fundamental principles of mechanics

(Newton's Laws). The traction force of the multicopter is calculated based on the Principle of Overlapping Forces; (iii) Variable mass body dynamics is the principle that applies in the study of Open Systems (with variable mass), including UAS platforms that integrate the phytosanitary spraying system for horticultural treatments.

Similar to the principles stated above, the principles underlying the integration of UAS systems as operational elements in the PA have the following basic ideas:

i. The *EVI* principle - Enhanced Vegetation Index or the principle of determining the vegetation index by aerial mapping using agri-drones for monitoring and multispectral vegetation scanning to determine the health of the agricultural crop;
ii. *ZP* principle - Zero Pollution or the principle of automatic input control (air-water-soil) in a horticultural process that tends to "zero pollution" by using SRS systems;
iii. Principle *ROI* - Return on Investment or the principle of maximum return on investment in precision farms by optimizing managerial decisions in a data-based PA.

These basic principles regarding the integration of UAS platforms in PA (agriculture-4.0) aim at the development from the "farm ≡ start" point of the FFS - Farm to Fork Strategy promoted in EGD - European Green Deal. Is shown in Fig. 4 a), the block diagram of agri-food chain management from farm to consumer.



a) The block diagram of FtoF Strategy **b) The flow diagram for a horticultural process**

Fig. 4 – Material and method for Farm to Fork strategy in European Green Deal

The promotion of *EVI, ZP & ROI* in precision agricultural farms makes it possible to analyse in real time the state of horticultural processes, so that farmers can make optimal decisions to save money, while protecting the environment and sustainably transforming reported food production, to the future population growth. Valuable benefits (ROI optimization) come with objective information obtained through sensors and monitoring devices, to maximize productivity and sustainability. Data-based agriculture (inputs / outputs) through the transfer functions of the horticultural process increases efficiency by avoiding the misuse of resources and environmental pollution. It is show in Fig. 4 b), the *eAGRI-EASY* concept for horticultural farms, based on the "*FtoF*" strategy.

- ***The "EVI" principle***

NDVI or the vegetation index of the normalized difference is the graphical indicator, relatively simple, which is used to analyse non-contact measurements, made from a UAS platform in space, in order to assess the vegetation state of the observed target. The following relationship gives the formula for calculating the vegetation index for the monitored crop: $NDVI = (NIR – RED) / (NIR + RED)$. Graphic images can be obtained in the form of a colour graphic indicator using even digital RGB cameras through simple modifications to obtain results compared to those obtained from multispectral cameras designed to monitor the health of plants. The vegetation index of the normalized difference is called the shorter index of "greenery", is an index of photosynthetic activity of plants, currently the most used vegetation index. Vegetation indices are based on the observation that different surfaces reflect different types of light differently. Photosynthetically active vegetation, in particular, absorbs most of the red light (RED) that hits it, while reflecting much of the near-infrared (NIR) light. Dead or stressed vegetation reflects more red light and less infrared light.

The *Enhanced vegetation index* (EVI) has been developed as an alternative vegetation index to address some of the limitations of NDVI. EVI has been developed specifically to: (i) be more sensitive to changes in high biomass areas (a serious shortcoming of NDVI); (ii) reduces the influence of atmospheric conditions on vegetation index values and correct the background signals of vegetation. EVI tends to be more sensitive to differences in vegetation, such as the Leaf Area Index (LAI), vegetation structure, and plant phenology and stress than NDVI, which generally only responds to the amount of chlorophyll present. With the launch of MODIS sensors, NASA adopted EVI as a standard MODIS product that is distributed by USGS (https://www.usgs.gov/). The greenery index EVI is calculated with the relation:

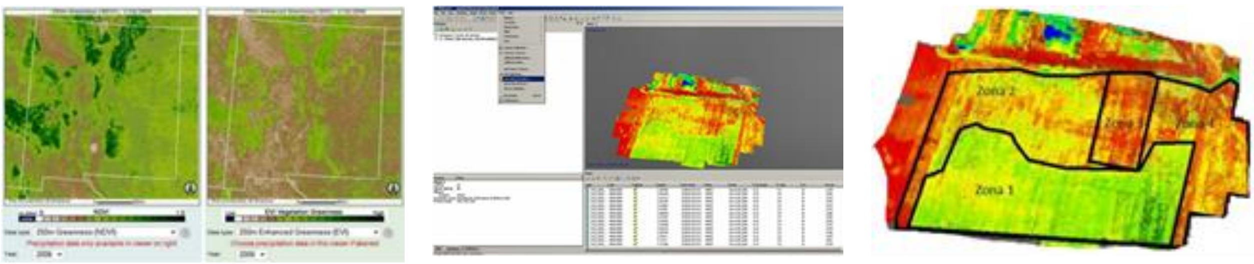
$$EVI = G \cdot \frac{NIR - RED}{NIR + C_1 \cdot RED - C_2 \cdot BLUE + L} \quad (1)$$

where: (i) *NIR, RED,* and *BLUE* are the fully or partially corrected atmospheric surface reflectance's (for Rayleigh scattering and ozone absorption); (ii) *L* is the background adjustment of vegetation for the correction of nonlinear, differential, and radiant transfer of vegetation; (iii) C_1 and C_2 are the coefficients of the term aerosol resistance (which uses the blue stripe to correct the influences of aerosols in the red stripe); (iv) *G* is a gain or scaling factor. The coefficients adopted for the MODIS EVI standard algorithm: $L = 1$, $C_1 = 6$, $C_2 = 7.5$ and $G = 2.5$.

As software / hardware requirements, EVI requires input data measurements of the surface reflectance of the blue, red, and near-infrared bands. Given the appropriate inputs, EVI is quite easy to calculate using image processing software (e.g., ERDAS Image, ENVI, IDRISI) or GIS software that can do raster processing (e.g., ArcGIS with Extension for Space Analysers, GRASS). However, most EVI applications have used the MODIS EVI standard products that can be downloaded from the USGS LPDAAC (https://lpdaac.usgs.gov/).

Fig. 5 a) and b), gives as an example the colour graphic indicator for the two variants of the vegetation index: MODIS EVI (b) compared to NDVI (a) for a location at the same time. The NDVI image shows a larger area in dark green because NDVI loses its sensitivity to changes in vegetation in areas with superior biomass. The EVI image maintains a more consistent sensitivity to changes in vegetation and, in this example, has a more uniform distribution of the greenery values of the vegetation regardless of aerosols.

Within the national program NUCLEU (PN 18300101/2018) of INMA, works were carried out to determine the vegetation status of the analysed crops based on spectral maps made by aerial mapping with the agricultural drone FAE750H. Several monitoring flows were carried out {cartographic scanning → process → spectral analysis → managerial decisions} for the culture investigated in the precision farm by aerial mapping with a agri-drone of the INMA institute's, [4].



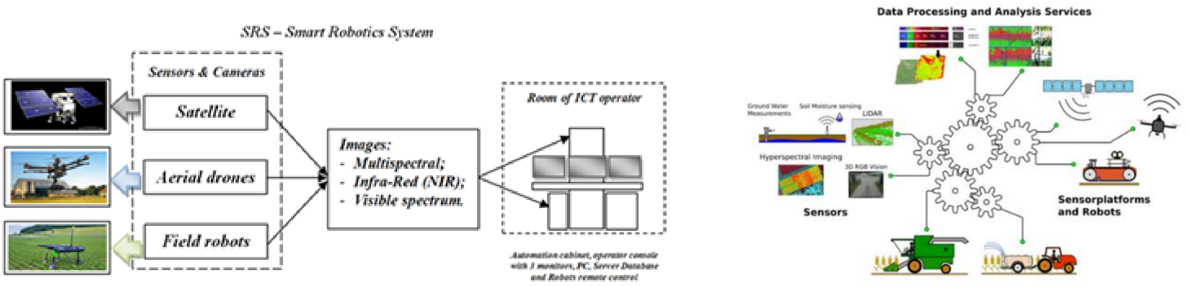
a) NDVI **b) EVI** **c) FIELD INMA** **d) A method to identify areas**

Fig. 5 – a) and b) Details of vegetation index NDVI versus EVI (source: http://rangeview.arizona.edu); **c) NDVI map of the vegetation status of the monitored crop; d) Application of the INMA visual-intuitive method to identify areas with homogeneous characteristics,** [2]

The program Pix4D converts multispectral images by evaluating areas with different productivity through NDVI vegetation indices, using RGB images to generate high-resolution orthomosaic images. The results obtained by the process area images with Agisoft Photoscan are displayed in Fig. 5 c) and d). Following the identification of problems for each area, the farm manager will establish the phytosanitary treatments to be applied, respectively the application of insecticides or georeferenced fertilizers. For this purpose, the georeferenced maps with the homogeneous NVDI areas will be exported and on them, the routes for applying phytosanitary treatments using GPS technology will be generated.

- ***The ZP principle***

The ZP principle – Zero Pollution is the principle of automatic control of inputs (air-water-soil) in a horticultural process to strive for "zero pollution" through advanced management of inputs/outputs using SRS systems. In Fig. 6 a) are presented the ways of collecting data from the agricultural environment (in-situ) for processing according to the new concept. The interoperability between agricultural machinery, sensors, and data services, standardized by ATLAS (www.atlas-h2020.eu/) for full operator control over the data, is show in Fig. 6 b).



a) *FIELD* concept for data-driven agriculture **b) Interoperability in Digital Agriculture**

Fig. 6 – Automatic control of *INPUTS / OUTPUTS* for *ZP* agricultural process
(Link source: https://www.atlas-h2020.eu/wp-content/uploads/2020/06/ATLAS_reference_architecture_1.0_2020.pdf)

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 "*ZP* – Zero Pollution" and f_q variables, randomly determined at the t time throughout the *T* period of a horticultural process:

$$\left[F_{ZP}(f_q, t)\right] \quad (2)$$

where f_q – represents the quality indicator functions for each abiotic component (inputs), as follows:

i. Air: $f_q \equiv f_a(x_1, \ldots, x_i, t)$, for $q = a$ and $i = \overline{1, l}$, $l \in N$;
ii. Water: $f_q \equiv f_w(y_1, \ldots, y_j, t)$, for $q = w$ and $j = \overline{1, m}$, $m \in N$; (3)
iii. Soil: $f_q \equiv f_s(z_1, \ldots, z_k, t)$, for $q = s$ and $k = \overline{1, n}$, $n \in N$.

Any of the Physical-chemical pollutants x_i, y_j, z_k of the variables in the fields of definition of the above functions shall be determined over time by continuous measurement (direct or non-contact sensor) or discontinuous measurement (sampling and laboratory analysis) according to the current technical possibilities existing in precision farms. Pollution is the contamination of the environment (including the agricultural environment) with materials that interfere with human health, quality of life, or the natural function of ecosystems. Even though sometimes environmental pollution is a result of natural causes, most of the polluting substances come from human activities. The following categories are distinguished: physical pollution, chemical pollution (produced by various substances released into the environment in gaseous, liquid, or solid particle form), biological pollution (with pathogenic germs, organic substances, etc.). In general, each pollutant [e.g., $y_j(t)$]

has a threshold value p_{p_j} the overcoming of which is considered dangerous for the contamination of the environment and, implicitly, of human health. Starting from this consideration, the pollution variable regardless of the abiotic component of the environment is defined a-dimensionally, as follows:

$$y_j(t) = \begin{cases} 0.1 * 10^{-m}, & for \;\; y_{t_j} = 0\,; \\ \dfrac{y_{t_j}}{p_{p_j}}, & for \;\; y_{t_j} \in \left(0, p_{p_j}\right]; \\ Emergency, & for \;\; y_{t_j} > p_{p_j} \end{cases} \qquad (4)$$

where:

y_{t_j}- represents the measured value of pollutant $y_j(t)$ at the *t* time; $j = \overline{1,m}$, and $m \in N$, polluting agent group *j*;

$y_j(t) \in (0,1]$ - it is always a-dimensional value; $t \in (t_0, T)$, and *T* represents the period of a horticultural process.

Replacing the relationships (4) in (3) for each pollutant in its group, we obtain the detailed relations of the quality indicator functions for each abiotic component. The relation (5) shows only the indicator f_q for the water input, the other two functions are obtained similarly:

$$f_w(y_1, \dots, y_j, t) = \begin{cases} \prod_{j=1}^{m} y_j(t), & var.1 \\ \frac{1}{m} * \sum_{j=1}^{m} y_j(t)\,, & var.2 \\ \left(\prod_{j=1}^{m} y_j(t)\right)^{\frac{1}{m}}, & var.3 \\ \frac{\sum_{j=1}^{m} \omega_j \cdot y_j(t)}{\sum_{j=1}^{m} \omega_j}, & var.4 \end{cases} \qquad (5)$$

Regardless of the calculation variant and apart from the extreme values {0, *Emergency*}, the quality indicator function always makes subunit values based on the considerations made. Variants 1 ÷ 4 will be allocated in the calculation logic of the PLC or PAC that supervises the horticultural process depending on the abiotic component of the agricultural environment, the monitored culture and the sensory equipment used for monitoring. Based on the relationships of (3) and (5) for each abiotic air-water-soil component of the agricultural environment, the relationship (2) for the global indicator function ZP, becomes:

air **water** **soil**

$$F_{ZP}(f_q, t) = \left\| \begin{matrix} f_a(x_1, \dots, x_i, t) & 0 & 0 \\ 0 & f_w(y_1, \dots, y_j, t) & 0 \\ 0 & 0 & f_s(z_1, \dots, z_k, t) \end{matrix} \right\| \begin{matrix} \leftarrow air\ pollutants \\ \leftarrow water\ pollutants \\ \leftarrow soil\ pollutants \end{matrix} \qquad (6)$$

where: $i = \overline{1,l}$; $j = \overline{1,m}$; $k = \overline{1,n}$; and $l, m, n \in N$

Making the appropriate replacements in the relation (6) for a working variant adapted to the horticultural process, the following *global indicator function ZP* is obtained:

$$[F_{ZP}(f_q, t)] = \left\| \begin{matrix} \left(\prod_{i=1}^{l} x_i(t)\right)^{\frac{1}{l}} & 0 & 0 \\ 0 & \frac{1}{m} * \sum_{j=1}^{m} y_j(t) & 0 \\ 0 & 0 & \frac{\sum_{k=1}^{n} \omega_k \cdot z_k(t)}{\sum_{k=1}^{n} \omega_k} \end{matrix} \right\| \qquad (7)$$

Determinant attached to the global indicator function *ZP* (zero pollution) $\left[F_{ZP}(f_q,t)\right]$ take values in the [0,1] range. A subunit value in the vicinity of "0 + 0" indicates that the horticultural process is environmentally friendly.

$$det.\left[F_{ZP}(f_q,t)\right] = \left|F_{ZP}(f_q,t)\right| \xrightarrow{t=T} 0 \quad (8)$$

where: $t \in (t_0, T)$, *T* being the period of a horticultural production process.

The ZP principle will simulate numerically in code Mathcad Prime 7. Laboratory tests for the validation of numerical simulations will be done in LabVIEW NXG code on a NI CompactRIO modular platform that interfaces with field-sensors. The precision farm where the experiments are performed must have an anemometer for air quality, a multiparameter probe for water quality indicators, immersed in the basin from which the crop is irrigated, as well as electrodes or soil sensors for field measurements. Subsequent facilities with an agri-drone and SRS systems will allow the development of comparative case studies. The experiments will last at least one year, during which time the theoretical method of the ZP principle will be upgraded and the results of the research will be disseminated through articles and / or other future directions of research.

- ***The ROI principle***

The ROI principle strengthens Edge Innovation Actions (EIA) undertaken in the PA farms through the following activities: (i) Meso-economic analysis of the socio-economic problems of the IP in order to identify the main socio-economic problems of farmers, as well as the existing and potential threats and opportunities for the competitiveness and profitability of the primary sector; (ii) Assess the electiveness of policy measures by assessing the effectiveness of current implementations of agrarian policies towards the sustainability of agriculture by adapting precision cultivation technologies and practices; (iii) Meso-economic analysis of the impact and conditions of dissemination of innovation in agricultural chains by using the Q software methodology; (iv) Assessment of return on investment (ROI) through the NPV (Net Present Value) indicator.

The PA refers to a suite of innovative technologies that can reduce entry costs by providing the farm operator with detailed site-specific information that can be used to optimise land management practices (National Research Council, 1997). EIA's benefits for the environment come from the more targeted use of inputs that reduce losses from excess applications and from the reduction of losses due to nutrient imbalances, weed escapes, insect damage, resistance to pesticides, etc. (*Bongiovanni, 2004*).

The adoption of "edge" innovations requires a significant investment; therefore, it is recommended to identify the economic and financial viability of these innovations by using the principle of ROI (*e.g., Pagiola, 2001*). Among the different methods of estimating ROI, we keep here the NPV net present value method, (*Grier & Nagalingam, 2000*). Traditional and efficient method, VAN indicates the viability, of a project deducting the cost of the initial investment from the current value of a uniform series of future capital, using the corresponding interest rate. Therefore, the higher the NPV, the greater the attractiveness of the project. The NPV is calculated by the following formula:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+K)t} - I_0 + \sum_{t=1}^{n} \frac{I_t}{(1+K)t} \quad (9)$$

where:

CF_t - cash flows in each period of the project t (cash benefit);

K - discount rate represented by the minimum profitability required by the project;

I_0 - the value of the investment at zero moment (start of the project);

I_t - the amount of investment in each subsequent period.

In order to carry out the evaluation method in the precision farm, all the necessary data will be collected directly from the established case study. The NPV is then calculated to assess the return on investment of the proposed practices. In addition, as agricultural activity is generally subject to unforeseen risks, such as changes in market prices, unforeseen weather conditions or extra-invasive species, a sensitivity and risk analysis will be carried out using software Q. Sensitivity analysis allows to verify the effect of changing one or more input variables on the value of output variables, i.e., how much the results can influence the variation of a given.

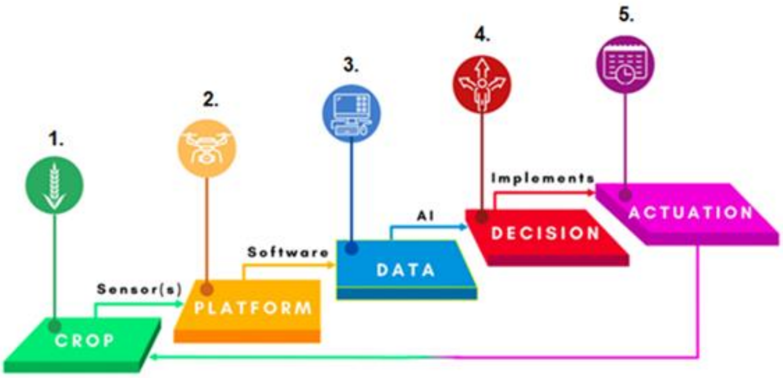
RESULTS AND DISCUSSIONS

Purpose and operational utility of UAS

Currently, the recommended agricultural production environment for the use of agri-drones is the horticultural environment. Horticulture focuses on vegetable growing, fruit growing, viticulture, floriculture and other crops that generally use small areas or plots with a wide variety of mixed crops, while agriculture focuses on large primary crops that use arable land of tens or hundreds of hectares. Payload and flight range are two essential features of UAVs that today limit the use of drones as UAS operational platforms in agriculture, especially for large crops. However, aerial crop monitoring and mapping operations, spray-based phytosanitary treatment operations and / or emergency logistics transport in isolated or hard-to-reach areas make agri-drones' useful operational tools in many agricultural production environments.

Horticultural farms have a wider opening to PA. The purpose of the PA is to apply a farm's limited resources more efficiently to achieve maximum yield. Due to its nature, PA requires a lot of data for processing and to provide optimal managerial decisions in the operation of the farm. Thus, UAS agri-drones play a crucial role in aerial mapping in providing primary crop health data and creating large databases. Digital agriculture based on the big databases provided by UAS systems (e.g., *EVI* spectral maps) optimizes the horticultural process for return on investment (*ROI*) in sustainable zero pollution (*ZP*) conditions through the advanced management of agricultural data from the cloud.

So, agri-drones are rapidly transitioning from the military systems (equipped with UAVs) to precision agriculture (equipped with UAS equipment), in order to provide the necessary support to farmers for surveillance of large crops and / or in carrying out plant protection or stimulation operations. This revolutionary leap contributes to considerable savings (the desire of any farmer is to produce more at lower costs), as well as to the revolution of traditional agriculture towards smart agriculture or PA.



1. Crop:	2. Platform:	3. Data:	4. Decision:	5. Actuation:
- Precision and intelligent agriculture; - Social and economic impact; - Management areas;	*- Remote sensing (satellite and UAS); - Proximal detection (land vehicles);*	*- Big databases; - IoT; - Mapping; - Information systems (GIS, FMIS);*	*- Artificial intelligence (AI); - Decision Support Systems (DSS);*	*- Variable rate applications (VRA).*

Fig. 7 - The architecture of operational flow for the crop process towards agriculture-5.0, [1], [8]

A new approach driven by digital technology implies that most 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 essential, and the information-based management cycle illustrated in Figs. 7 offers a practical approach that easily includes the agricultural tasks of a new level agricultural concept - 5.0. PA based on large databases (*AgroFlyData*) of crops and the agricultural environment, with the help of UAS and SRS systems that incorporate AI execution techniques, lays the foundations for a sustainable agriculture of the future (agriculture-5.0). The actions corresponding to each level 1 ÷ 5 of the operational flow of the horticultural process are listed in the legend in the following figure.

CONCLUSIONS

Similar to the principles of classical physics that underlie the CAE (Computational Aided Engineering) design of UAS platforms, the principles underlying the integration of UAS and SRS (Smart Robotic Systems) as operational elements in agriculture-4.0 have the following basic ideas: (i) *EVI* principle, Enhanced Vegetation Index is principle of determining the vegetation index by aerial mapping using agri-drones for monitoring and multispectral scanning of vegetation to determine the health of the agricultural crop; (ii) *ZP* principle, Zero Pollution is principle of automatic inputs control (air-water-soil) in a horticultural process that tends to "zero pollution" by using SRS systems; (iii) *ROI* principle, Return on Investment or the principle of maximum return on investment in precision farms by optimizing managerial decisions in a data-based agriculture. These principles aim to develop from the primary point of the "START ≡ precision farm", the Farm to Fork strategy (*FFS*) promoted by European Green Deal (*EGD*) and, as a result, their mathematical models will be implemented software in the new AgroFlyData (*AFD*) concept for agriculture-5.0.

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