ACTA IMEKO
ISSN: 2221-870X
June 2020, Volume 9, Number 2, 83 - 88

Introducing EVJA: a 'rugged' intelligent support system for precision farming

Niccolò Loret[1], Antonio Affinito[2], Giuliano Bonanomi[3]

[1] *EVJA R&D, EVJA Neaples, Italy*
[2] *EVJA CTO, EVJA Neaples, Italy*
[3] *Department of Agricultural Sciences, Federico II University, Neaples, Italy*

ABSTRACT
Precision agriculture is a farming system based on the combination of detailed observations, measurement, and rapid response used to optimise energetic input to maximise crop production. Precision agriculture uses a Decision Support System (DSS) for optimising farm management. In this context, 'EVJA: Observe, Prevent, Improve' (or just 'EVJA') is an intelligent support system used for precision agriculture. A vast set of data (temperature, relative humidity, deficit of vapour pressure, leaf wetness, solar radiation, carbon dioxide concentration, and soil moisture) is continuously collected, submitted to a local control unit, and processed through algorithms specifically developed for different crops. On the other hand, farmers can access EVJA from their PC and mobile devices, and they may monitor complex agronomic data analysis presented in a user-friendly interface.
In this article, we show how EVJA works and how its output can be used to assess the health status of plants through a specific set of functions. Moreover, we show the methodology utilised to develop useful predictive models based on this information.
Specifically, we describe a predictive algorithm that is capable of predicting the infection risks of downy mildew for baby leaves plantations and for Fusarium ear blight of wheat.

Section: TECHNICAL NOTE

Keywords: precision farming; internet of things; predictive models; bremia lactucae; hyaloperonospora parasitica; fusarium head blight.

Citation: Niccolò Loret, Antonio Affinito, Giuliano Bonanomi, Introducing EVJA: a 'rugged' intelligent support system for precision farming, Acta IMEKO, vol. 9, no. 2, article 13, June 2020, identifier: IMEKO-ACTA-09 (2020)-02-13

Editor: Mauro D'Arco, University of Naples Federico II, Italy

Received February 28, 2020; **In final form** May 14, 2020; **Published** June 2020

Funding: Some of the research projects described in this article are funded by the iGUESS-MED PRIMA programme, funded under Horizon 2020, the European Union's Framework Programme for Research and Innovation.

Corresponding author: Niccolò Loret, email: niccolo@evja.eu

1. INTRODUCTION

Smart farming is revolutionising agriculture, helping farmers to increase the quantity and the quality of their products. When we refer to smart farming, we are talking about a vast array of systems, differing in terms of their technology and scope. However, at its core, smart farming consists of sensors managed by software that is aimed at making the farmers' job more efficient and effective. Some smart farming products focus on robotics, machine automation, location technology, or data analysis. When smart farming is based on IoT systems, it is called precision farming [1][2][3][4]. Precision farming follows a four-step cycle that starts with the monitoring of the plants via sensors, followed by the diagnostics of the collected data and ending either with the decision-making of the farmer or with the activation of another system; for example, in automatic irrigation systems connected to the precision farming platform. The result is a more controlled crop cycle, with plant and weather conditions monitored metre by metre, and a more accurate intervention by the farmers, with action undertaken only when it is really needed. The advantages are significant: less pesticides and fertilisers are used; irrigation is more efficient; and the final product is healthier and more abundant. Said results are achieved with minimum impact on the environment, leading to a win-win situation for the farmers, consumers, and the environment.

We now introduce 'EVJA: Observe, Prevent, Improve' (or just 'EVJA'), a precision farming system of our design. EVJA is an intelligent support system that helps farmers optimise the usage of chemical products and water. By using IoT and artificial intelligence, EVJA allows farmers to monitor their fields in real time, wherever they are. EVJA gathers data from a network of customisable sensor nodes (see Figure 1) connected to servers

Figure 1. The appearance of an EVJA sensor node.

where those data are processed. Thanks to its self-calibrating agronomic models, EVJA helps farmers prevent plant diseases. EVJA is equipped with a simple and intuitive interface (see Figure 2), which makes it very easy to use. It is available for every kind of crop and offers specific advanced features for greenhouse farms. We extensively describe the entire system in the following paragraphs, for the data collection process and data analysis.

2. STATE OF THE ART

IoT has the potential to monitor irrigation and productivity, and the data gathered by IoT sensors have the ability to provide information about the overall performance of the crops. Existing monitoring systems use drones and weather stations, which are inappropriate for greenhouse crops. Indeed, EVJA includes the first predictive algorithm for horticultural products in the European Union, while the main direct competitors commercialise solutions that address generally all type of crops, without focus and verticalisation on specific crops and weak results. On the other hand, greenhouse monitoring systems are often designed for fully climate-controlled environments, closer in concept to a scientific laboratory than a farmhouse, while EVJA's 'rugged' sensor nodes are designed to be handled roughly, in any kind of working conditions.

The main features characterising the EVJA system are:

- technological: the integration with advanced predictive models;
- product: the bundling of hardware and software in a single solution, which allows for a seamless user experience; and
- business: the high scalability of EVJA, which allows for targeting agricultural businesses anywhere in the world.

Indeed, compared to many other systems that are available, the EVJA hardware works not only with WiFi or mobile coverage but also everywhere else due to the use of an innovative communication technology called a Long-Range (LoRa) network [5], which can fully operate with radio frequencies. Furthermore, EVJA is a software, which is more flexible, more extendable, and more user-friendly than that of the majority of its peers.

The EVJA system is based on a Software as a Service (SaaS) model, which offers an array of features, including real-time monitoring, forecasting, management, business intelligence, and social features like chat and media sharing.

Farmers can monitor and manage everything, in each field, directly from their desktop, tablet, or smartphones. They can mark every event, like an above-average harvest, and go through the history to see trends and correlations between such events and the key factors registered by the sensors. If a worker in the field spots a plant affected by a parasite, they can take a picture and share it with the agronomist in order to check the type of disease and take immediate action.

The hardware consists of a device with sensors to be installed in fields in an intuitive 'plug and play' manner and does not require maintenance. The sensors collect all the relevant data, such as humidity, temperature, light, and soil status.

The EVJA system is totally wireless. It does not need cables for its power supply nor for communication with other devices. It includes an electronic package containing a customisable processing unit and a wireless communication unit to communicate wirelessly with external systems.

More specifically, EVJA's hardware includes:

- the base station ($12 \times 12 \times 8$ cm³), which has a robust waterproof enclosure and covers a homogeneous area of about 3 hectares;
- the battery, which is recharged using the internal or external solar panel ($23 \times 16 \times 2$ cm³) – the rechargeable battery has a load of 6600 mA h, which ensures non-stop working time for a month;
- sensors, which are used to measure temperature, leaf wetness, humidity, and solar radiation; and
- mobile radio options – WiFi and the LoRa network.

3. THE EVJA SYSTEM IN DETAIL

The node's core is a microcontroller powered by a battery charged by a solar panel. Sensor probes can be easily attached to the device by simply screwing them into the bottom sockets. In the same way, sensor probes may be easily replaced. The basic EVJA functions need just temperature, humidity, leaf wetness, and solar radiation sensors. However, the entire system is easily customisable, and new sensors can be added depending on the user's requests. As we will explain in detail later, the next EVJA release will be integrated with soil moisture sensors. In addition

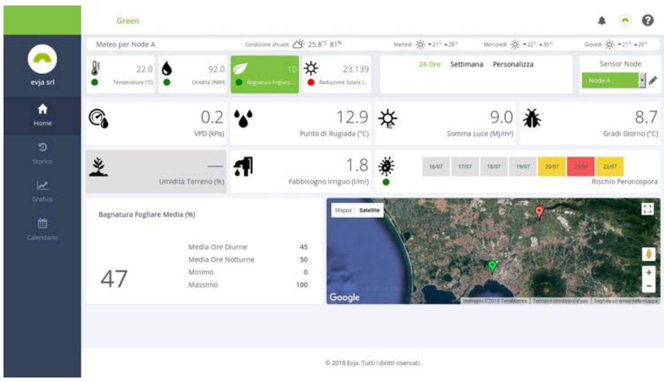

Figure 2. EVJA's simple and intuitive interface

to the agronomic observables, the system gathers data about the state of the system, such as GPS, accelerometer data, the status of the battery, and GSM signal power. The data is collected by the sensors at every time interval (fixed by the system manager). At the end of the process, an antenna sends both agronomic and diagnostic data to the servers. The chosen data transmission protocol is very flexible, making use of 4G and WiFi protocols. In the case of poor coverage, a customised radiofrequency network is deployed ad hoc using Gateway to deploy a 'star' network or a mesh network of sensor nodes. In the case of a temporary lack of signal, the measurements are stored in a memory inside the control unit and are then communicated to the server when the signal is restored. The data stored in the servers are available to the users, who will always be able to access the required information through a simple and responsive interface (in Figure 2) on their smartphone or laptop. Logging into the interface, the user can see historical data in the form of simple graphics (as shown in Figure 2), select the required time intervals, and check the reports about thresholds exceeded, parasites, and other useful information on plant health.

4. EVJA ALGORITHMS

EVJA is equipped with several generic functions that are useful for defining plant status and needs, and it also has custom-designed predictive algorithms specifically designed to keep parasites under control. We give below some examples to better explain how the system works and how farmers can use it to rationalise their activities and spearhead resources.

4.1. Functions

Using the EVJA interface, a farmer can check the conditions of a crop in real time. The system allows to fix thresholds for temperature, humidity, leaf wetness, solar radiation and other customisable observables (depending on the kind of sensors mounted on the device). In case those thresholds are exceeded, the system sends a warning email to the farmer. EVJA, however, does not just visualise those data. It also processes it in order to calculate the functions that are fundamental for depicting a clear picture of the plants' health status, such as dew point, Vapour Pressure Deficit (VPD), Growing Degree Days (GDDs), and evapotranspiration. The dew point is the temperature T_{DP}, to which air must be cooled to become saturated with water vapour. Dew point can be calculated through the formula:

$$T_{DP}(T,U) = \frac{c\left(\ln\left(\frac{U}{100}\right) + \frac{bT}{c+T}\right)}{b\left(1 - \frac{bT}{c+T}\right) - \ln\left(\frac{U}{100}\right)} \tag{1}$$

where b = 18.678 and c = 257.14 °C. When the air temperature is close to the dew point, the air is saturated with moisture, plant perspiration will not evaporate, and droplets will form on leaves. Dew point can also be called frost point if $T_{DP} < 0$ °; in this case, the system warns the user about the possible damage to the crops.

GDDs is a parameter with the dimensions of a temperature, expressing the heat accumulation by plants and insects during their development. Ambient temperature influences plants and pests' rate of growth; therefore, when specific predictive models calculating some harmful insect outbreak probability or plant productivity are lacking, calculating the GDDs can be a simple preliminary step in setting an indicator [6] [7]. A simple estimation of the GDDs can be obtained by the formula

$$GDD(T_m, T_M) = \int T(t) - T_m \, dt$$
$$\left(\frac{1}{N}\sum T_i - T_m\right)_{T_m<T<T_M} . \tag{2}$$

where t is the time, N is the number of measures performed in one day,[1] n is the total number of measures, and T_m and T_M are respectively the minimum and maximum temperatures defining the survival range of a living being. Many calculation tricks, from trapezoid to Monte Carlo formulae for the numerical calculation of integrals, could make the approximation in Equation (2) more reliable. However, since phenomenological tables are compiled by taking into account the rough approximation of the rectangles, it is always better to stick with the simpler GDDs definition.

For many species of insects, the time interval in which $T < T_m$ is called diapause; in that period, their development process basically stops, only to resume when weather conditions are more favourable. Climate changes have recently affected the reliability of this indicator for pest control, because given the rising average temperatures in winter, many insects do not go through a diapause as they used to a few decades ago. Moreover, a crop can be infested by many different pests, like aphids or non-diapausing insects. That is why EVJA's GDDs numbers should be used for pest control purposes only, with the careful assistance of an entomological specialist. Much simpler is the use of the GDDs indicator to predict the time left for a plant to develop and flourish: using weather forecast data, the system can estimate future heat accumulation and predict the period in which it is more likely that the plant will reach the GDDs value related to their full development (by confronting the system with well-known phenomenological tables). In this way, farmers are assisted in planning their future activities, such as harvesting or determining the right amount of irrigation needed by their crops in the near future. The system will then help farmers to save water through other parameters.

VPD is the difference between the vapour pressure within the leaves and that of the atmosphere:

$$VPD(T,U) = P_s(T_l) - P_a(T_a, U_a) \tag{3}$$

where T_l is the leaves' temperature, and (T_a, U_a) are the temperature and humidity measured by the sensors. VPD is an indicator of the water flow within the plants, providing information on the efficiency of the inner steam pump in the plant's stem. Knowing both VPD and evapotranspiration ET, the user can determine the actual plants' need for water. Evapotranspiration is estimated in EVJA through a simplified version of the Penman-Monteith equation [8][9]:

$$ET_c(K_c, S, P_s) = K_c ET_0(S, P_s) \tag{4}$$

where S is a function characterising the role of the solar radiation, and K_c is the crop coefficient (which depends on the plants' growth stage).

1 One should bear in mind that GDDs are defined by taking into account average daily temperatures, while the EVJA system can perform and store hundreds of measures each day.

A clearer indication about whether is appropriate to irrigate a crop can be given by integrating some information about the actual soil moisture into the system.

4.2. Soil moisture measurement and water saving

Water wastage in agriculture and excessive fertilisation are two important issues in present-day agriculture. Problems related to the excessive and non-rational use of nitrogen fertilisers are related both to the accumulation of nitrates and nitrites in soil and plants as well as to the leaching of these nutrients to ground and surface water. While nitrates and nitrites in food are precursors of carcinogenic substances to humans, from an environmental point of view, a high concentration of these ions in water sources favours the phenomenon of eutrophication. Management of water and nitrogen fertilisers in agriculture are strongly interconnected practices: the optimal absorption of fertilisers by plants depends mainly on temperature and soil moisture [10].

EVJA is being upgraded with a dynamic forecasting model that simulates the mineral nitrogen content in the soil within an integrated sensor-based irrigation system that provides data on atmospheric climatic conditions, integrated with soil moisture, soil temperature data, and weather forecasts. This will potentially be a key tool for high-tech agriculture aiming to reduce the adverse environmental impacts thereof. The system eliminates the difficulties in reading and interpreting data, facilitating the involvement of farmers in the field, who will receive real-time updates on soil water content and crop water needs directly on their mobile device, allowing for effective and efficient interventions.

The system will acquire data from wireless soil moisture sensors (Figure 3) to run computer simulations [11], which are validated through a chemical analysis of the soil in order to determine the actual nitrogen content in its different forms (total, organic, nitrate, and ammonium, which may be quantified through more advanced sensors such as those in [12][13]).

4.3. Downy mildew predictive model

Since during the first years of EVJA's life, our activity focused mostly on baby leaf crops, we studied a very reliable predictive model for downy mildew of lettuce (*Bremia lactucae*) and rocket (*Hyaloperonospora parasitica*). Those oomycetes have a complex biological cycle [14][15] divided into many phases: a sporangia releases a large number of spores in the atmosphere, which eventually land on the plant's leaves, where they develop (with the right climatic conditions) into zoospores.

Again, given the right climatic conditions, the surviving zoospores will then infect the plant. It can take some days for downy mildew to properly develop, but after some time, which can be estimated by taking into account the temperature, it can affect the entire crop, with devastating effects.

We managed to parametrise this process, identifying the key conditions allowing each stage of the aforementioned cycle to take place. When the system identifies the ideal conditions for the zoospores to survive and penetrate the plants' leaves, it calculates the approximate date of the manifestation of the symptoms (see Figure 4) and sends a warning to the farmers. The warning can be visualised through an easy-to-read calendar (see Figure 2), where the user can also add annotations, which are useful to us as feedback. That feedback is actually fundamental to us, since it allows us to validate the algorithm with real data, adjusting the parameters and the functions in close relationships with the farmers.

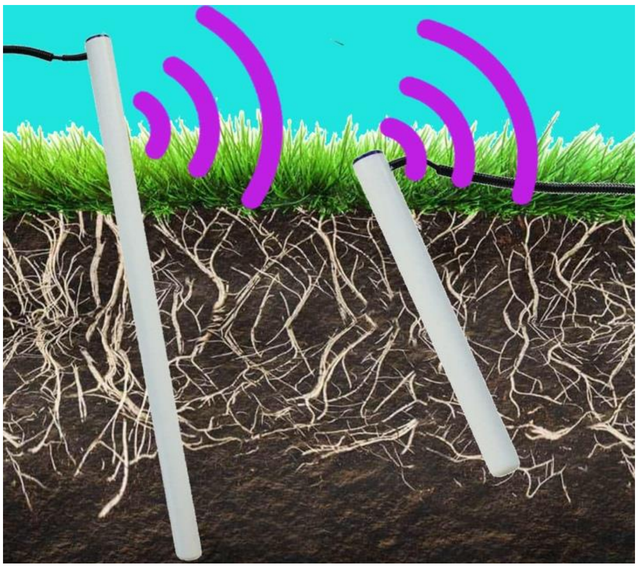

Figure 3. Wireless soil moisture sensors to be integrated in the EVJA system.

5. INTEGRATION WITH SATELLITE DATA

As we have seen in the previous sections, EVJA algorithms work based on a wide variety of data through which one can sharply determine the health status of the plants from their photosynthetic metabolism on the leaves to the water draining efficiency of roots, but they also reliably predict the onset of diseases and future growth rate. Those predictions tend to be correct for plants near to the control unit and less reliable the more we step away from it. The plants are constantly monitored by the system, with a measurement rate of around fifteen minutes, and alarms are triggered any time an observable (like temperature) exceeds a certain threshold. Satellite information is, of course, inherently different from ground-gathered data: it allows us to monitor the crop in its entirety with a time interval between two measures of a few days, instead having localised data within minutes. Satellites and sensors give, then, two different kinds of information on the crop status. The first one is very well localised and dense over time, while the second is available only at given moments and concerns the crop in its entirety with a certain rate of precision. The best solution is therefore not to rely on a single source of information; rather, they should be integrated using custom-made algorithms.

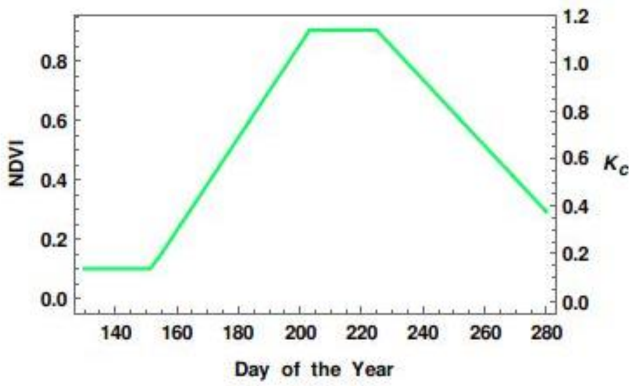

Figure 4. Ideal representation of the relationship between the NDVI and crop coefficient for a generic plantation. In this graphic, we modelized the behaviour of the crop coefficient over time for a fictitious plantation with K_{cmax} = 1.1.

Satellite images provide information on soil moisture only for the first 5 cm in depth, while soil moisture sensors planted in the ground provide data until 30 cm in depth. However, the number of sensors that one can plant into a crop is limited, and their data should be interpolated in order to approximate the water content of the soil in the points between the sensors. Finding out the correlation between the soil water content observed by the satellite in the first 5 cm with the one measured by the sensors in the spots where they are present gives a good starting point for adjusting the interpolation algorithms in order to better generalise the measures of the sensors to the entire field, with a good rate of reliability. Once that one gets a reliable grid that models the soil water content, it is possible to determine the crop water requirement, crossing over this information with evapotranspiration and VPD. In fact, while the reconstruction of the soil moisture in the first 30 cm of depth gives information about the roots' efficiency and health, the VPD provides indirect knowledge of the dispersion of water from the leaves to the atmosphere.

Satellite data enhances the estimation of the crop's complex evapotranspiration in a significant way. On the one hand, satellites record the heat flux from the ground, which is incorporated in the ET_0 term of Equation (4). On the other hand, taking into account the Normalised Difference Vegetation Index (NDVI) [14] solves the problem of the identification of the correct value to assign to the K_c coefficient. NDVI is defined as the reflection difference in the near-infrared (NIR) I_{NIR} and red spectrum I_{Red} divided by its total:

$$NDVI = \frac{I_{\mathrm{NIR}} - I_{\mathrm{Red}}}{I_{\mathrm{NIR}} + I_{\mathrm{Red}}} \tag{5}$$

Chlorophyll strongly absorbs visible light, while the cell structure of leaves strongly reflects near-infrared light. The layer along the bottom of a plant causes these reflections. When a plant becomes dehydrated, sick, affected by disease, etc. this layer deteriorates, and the plant absorbs more of that near-infrared light rather than reflecting it. Conversely, when near-infrared light hits a leaf on a healthy plant, it is reflected back. So, considering how NIR varies compared to red light provides an accurate indication of chlorophyll, which correlates to plant health. NDVI is also related to the average leaf area of vegetables in a crop; therefore, studying its evolution gives direct insight into the plants' growth stage. This information is of paramount importance to the EVJA system, since it allows us to determine the value of K_c as

$$K_c = K_c^{max}\, NDVI \tag{6}$$

avoiding being forced to rely only on farmers' estimates.

Satellite data are useful also for algorithms on plant disease outbreaks. In fact, those algorithms are highly reliable for plants that are close to the sensor node (for example, inside the same greenhouse), but they do not sufficient information about plants that may lie in a different area. It may happen, for instance, that while the climatic conditions all over the field are ideal for the development of a disease (e.g. *Peronospora Bremia*), but close to the control unit, the plants are just not wet enough or the temperature is too high for the zoospores to survive. In this case, the support system would not raise the alarm, and even if this is correct in theory, it would be ineffective. Of course, most of the time, the data gathered by the sensor node represent the conditions all over the field quite well, but such issues are not uncommon. As for the water requirement model, through satellite data, the system would be able to split a crop in smaller sections and find out the relationships connecting the climatic conditions in different areas, using the sensor node as a landmark for extrapolating the other data. In this way, it may be possible to run the predictive algorithms in each cluster, obtaining indications about plant disease all over the crop, thereby enhancing the algorithms' predictive power.

6. CONCLUSIONS

The EVJA system is currently working with top Italian farmers and monitoring more than 500 hectares. Using EVJA, farmers have been able to substantially reduce the number of chemical treatments required to hold off parasites and to save a large amount of water. Moreover, such an intelligent management of chemicals and water saves important economic resources.

In the near future, we plan to add many useful functions and algorithms to EVJA in order to improve the service quality we provide to the users: multi-spectral and hyper-spectral analysis to directly monitor plants' health; intelligent insect traps to keep track of many dangerous species; and a novel predictive model for the *Fusarium graminearum* fungus for adapting the EVJA system to work on outdoor crops (specifically cereals). The Fusarium head blight is a harmful parasite, since it releases deoxynivalenol within kernels, which is toxic for humans [17]. We managed to refine an algorithm whose skeleton is similar to the downy mildew one, while also taking into account rainfall (whose intensity should be measured with state-of-the-art sensors [18][19]) and dishomogeneities in T and U. We are now in the testing stage, and we are obtaining some encouraging results in confronting the algorithm's output with historical data.

In case the chemical treatment of such disease has not been possible, one can act a posteriori, isolating the infected areas and preventing the infection from spreading to the unaffected wheat inside the warehouse where the product is stored. We are improving the EVJA system to calculate the percentage of infected ears in the different zones of the crop and to report on a map the areas in which the infected plants have exceeded the concentration threshold considered acceptable. Using a geolocation system, EVJA should be able to suggest a smart path through the field in order to avoid the infected spots, telling the farmer to turn left or right, just like a common navigation system on a cell phone. Both in the case of Fusarium and downy mildew, as well as for every other predictive algorithm that will be implemented on the system, the most important thing for EVJA's operation will be to endlessly evolve accordingly to the farmer's feedback. This will allow us to adjust the functions' and algorithms' parameters in order to flexibly describe the situation on the fields and provide more precise suggestions. Ultimately, this progress will make agricultural work easier and more efficient.

ACKNOWLEDGEMENT

EVJA acknowledges a fruitful collaboration with Libelium Comunicaciones Distribuidas S.L. for the sensor node hardware supply and with Sentek Technologies for the soil moisture sensors.

REFERENCES

[1] W. Aulbur, R. Henske, G. Morris, G. Schelfi, Farming 4.0: How precision agriculture might save the world, Roland Berger Focus (February 2019) [Online]. Available:

https://alumni.rolandberger.com/pages/publications/2019/media/roland_berger_digitalisierung_als_chance.pdf
[2] K. Nowakowski, Farming: There's an App for That, National Geographic, (5 June 2018). [Online]. Available: https://www.nationalgeographic.com/environment/future-of-food/food-future-precision-agriculture/
[3] V. Arenella, P. Gabriele, F. Leccese, M. Cagnetti, L. Maiolo, A. Pecora, E. De Francesco, R. Đurović-Pejčev, Procedure for the space certification of a controller for soilless cultivation, Proc. of the 2016 IEEE Metrology for Aerospace (MetroAeroSpace), 2016, Florence, Italy, pp. 359-364. https://doi.org/10.1109/MetroAeroSpace.2016.7573241
[4] S. Kalidas, S. Bharadwaj, C. M. Vidhyapathi, B. Karthikeyan, Wireless node-base automatic irrigation control system, ARPN Journal of Engineering and Applied Sciences 12(19) (2017), pp. 5379-5383. [Online]. Available: http://www.arpnjournals.org/jeas/research_papers/rp_2017/jeas_1017_6364.pdf
[5] C. Swedberg, LoRa Solution Offers Wireless View Into SoilHealth, RFID Journal (Nov. 9 2018). [Online]. Available: https://www.rfidjournal.com/lora-solution-offers-wireless-view-into-soil-health
[6] S. S. Liu, X. D. Meng, Modelling development time of Lipaphis erysimi (Hemiptera: Aphididae) at constant and variable temperatures, Bulletin of Entomological Research 90 (2000). https://doi.org/10.1017/S0007485300000468
[7] R. A. Jaramillo, M. O. Guzman, Relationship between temperature and growth in Coffea arabica L. var. Caturra, Cenicafé (Colombia) 35(3) (1984) pp. 57-65. [Online]. Available: http://hdl.handle.net/10778/708
[8] J. L. Monteith, Evaporation and environment, Symposia of the Society for Experimental Biology 19 (1965). https://doi.org/10.4236/ojce.2016.63029
[9] C. H. Priestley, R. J. Taylor, On the Assessment of SurfaceHeat Flux and Evaporation Using Large-Scale Parameters, Mon. Wea. Rev. 100 (1972) pp. 81-9.[Online]. Available: https://doi.org/10.1175/1520-0493(1972)100<0081:OTAOSH>2.3.CO;2
[10] G. Bonanomi, G. B. Chirico, M. Palladino, S. A. Gaglione, D. G. Crispo, U. Lazzaro, B. Sica, G. Cesarano, F. Ippolito, T. C. Sarker, M. Rippa, F. Scala, Combined application of photo-selective mulching films and beneficial microbes affects crop yield and irrigation water productivity in intensive farming systems, Agricultural Water Management 184 (2017) pp. 104-113. [Online]. Available: https://doi.org/10.1016/j.agwat.2017.01.011
[11] G. Incerti, G. Bonanomi, F. Giannino, F. Carten, R. Spaccini, P. Mazzei, A. Piccolo, S. Mazzoleni, OMDY: a new model of organic matter decomposition based on biomolecular content as assessed by 13C-CPMAS-NMR, Plant and Soil 411(1-2) (2017) pp. 377–394. [Online]. Available: https://doi.org/10.1007/s11104-016-3039-2
[12] V. Pasquali, G. D'Alessandro, R. Gualtieri, F. Leccese, A new data logger based on Raspberry-Pi for Arctic Notostraca locomotion investigations, Measurement 110 (2017) pp. 249-256. [Online]. Available: https://doi.org/10.1016/j.measurement.2017.07.004
[13] F. Leccese, M. Cagnetti, S. Giarnetti, E. Petritoli, S. Tuti, I. Luisetto, A. Pecora, L. Maiolo, R. Durovic-Pejcev, T. Dordevic, A. Tomasevic, V. Bursic, V. Arenella, P. Gabriele, E. De Francesco, Electronic nose: a first sensors array optimization for pesticides detection based on Wilks' A-statistic, Proc. of the 5th IEEE International Workshop on Metrology for AeroSpace (MetroAeroSpace), 2018, Rome, Italy, pp. 440-445. https://doi.org/10.1109/MetroAeroSpace.2018.8453631
[14] H. Scherm, A. H. C. Bruggen, Concurrent spore release and infection of lettuce by Bremia lactucae during marnings with prolonged leaf wetness, Phytopatology 85(5) (1995). https://doi.org/10.1094/Phyto-85-552
[15] H. Su, A. van Bruggen, V. K. Subbarao, H. Scherm, Sporulation of Bremia lactucae affected by temperature, relative humidity, and wind in controlled conditions, Phytopathology 94 (2004) pp. 396-401. https://doi.org/10.1094/PHYTO.2004.94.4.396
[16] J. W. Rouse, R. H. Haas, J. A. Scheel, D. W. Deering, 'Monitoring vegetation systems in the Great Plains with ERTS', Proc. of the 3rd Earth Resource Technology Satellite (ERTS) Symposium 1 (1974) pp. 48-62. https://ntrs.nasa.gov/search.jsp?R=19740022614
[17] B. G. Shaner, Management and resistance in wheat and barley to Fusarium head blight, Annual Review of Phytopathology 42 (2004) pp. 135-161. https://doi.org/10.1146/annurev.phyto.42.040803.140340
[18] S. R. Barkunana, V. Bhanumathib, V. Balakrishnanb, Automatic irrigation system with rain fall detection in agricultural field, Measurement 156 (2020) p. 107552. https://doi.org/10.1016/j.measurement.2020.107552
[19] X. A. Mary, L. Rose, K. Rajasekaran, Continuous and remote monitoring of ground water level measurement in a well, International Journal of Water 12(4) (2018), pp. 356-369. https://doi.org/10.1504/IJW.2018.095397