Deployment and Assessment of a LoRa Sensor Network in Camelina [*Camelina sativa* (L.) Crantz] Culture

David Mostaza-Colado[1](✉), Pedro V. Mauri Ablanque[1], and Aníbal Capuano[2]

[1] IMIDRA Agro-Environmental Research Department (Madrid Institute for Rural, Agrarian and Food Research and Development), Ctra. A2 Km. 38.200 – Finca El Encín, 28805 Alcalá de Henares, Madrid, Spain
david.mostaza@madrid.org

[2] Camelina Company Spain, Fuente el Saz de Jarama, Madrid, Spain

Abstract. The use of LoRa sensors and IoT in farming is increasing progressively. For this study, we installed a series of LoRa soil moisture and conductivity sensors at 5 cm and 30 cm depth in a *Camelina sativa* (L.) Crantz cultivar. The information gathered by the sensors show how rain or irrigation water infiltrates in the soil. This allows the farmer to take decisions regarding the use of water in a very effective, cheap and reliable way. Although the use of LoRa sensors is more common in irrigated crops of high economic value and yield, the use of cheap sensors in rainfed agriculture can be a great contribution to manage the crop and add additional value to the production. It could provide information on the water stress and needs of the crop and be decisive in assessing whether, in large areas of dry land, it will be economically profitable to cultivate.

Keywords: Camelina · Smart agriculture · Precision farming

1 Introduction

The growing demand of new techniques for developing intelligent agriculture implies the adoption of technologies such as the Internet of Things (IoT) on farms. This kind of IoT technology allows the farmer to monitor his crop in real time and to identify the fundamental factors of agricultural production. The IoT sensors are connected to the Internet and transmit the information to a platform where it is collected and can be analyzed automatically [1].

There are several IoT systems, but currently the aim is to send certain environmental data such as temperature, soil moisture or irrigation water conductivity. Although these systems are useful for farmers, they can be useless if the crops are not in the right plot or have been affected by events such as a natural disaster or pests. Therefore, a monitoring system like this is an important factor in agriculture: 1) ensures and reduces the loss of productivity in high-yielding crops; 2) provides accurate and visual information to

L. Peñalver and L. Parra (Eds.): Industrial IoT 2020, LNICST 365, pp. 221–230, 2021.
https://doi.org/10.1007/978-3-030-71061-3_14

farmers; 3) improves decision-making in short time; 4) and ensures the right soil and plant conditions, thus increasing the value and yield of the crops [2, 3].

On the other hand, modern agriculture aims to answer the increasing worldwide need for food production. Thus, new technologies and solutions in the agricultural field provide an optimal alternative to collect and process information while improving productivity. At the same time, the alarming climate change and the growing water crisis require new and improved methodologies for the agricultural and farming fields of the modern era. Automation and intelligent decision-making are also becoming more important to fulfill this mission. Therefore, the combination of IoT with other technologies such as Big Data Computing or remote sensing is becoming increasingly popular and more often [4].

Consequently, IoT is an environment where objects, animals or people are equipped with unique identifiers capable of data transmission over Internet network without the need for human interaction. Thus, it has great potential and is one of the key areas for future development of internet services. New uses of IoT are being searched for and established, but most of the effort is in the area of solution standardization [2, 5, 6].

1.1 LoRa Technologies

The challenge arises when implementing a real-time visual monitoring system to control an entire farm and increases as the farm grows bigger or is in places with difficult access. It is not possible to wire the entire farm to deploy sensors, so IoT and technologies such as LoRa (short for long range) take advantage. This radio information packet handling technology is characterized by high tolerance to interference, low power consumption, long range and low data transfer rate. This allows the deployment of low-cost sensor networks in large areas like farms or woods. Thus, LoRa provides long-range and low-power consumption, a low data rate, and secure data transmission. It can be used with public, private, or hybrid networks to achieve a greater range than cellular networks. LoRa technology can easily integrate with existing networks and enables low-cost, battery-operated Internet of Things (IoT) applications. A single gateway can cover huge areas of square miles/kilometers. Therefore, LoRa networks are considered low-power wide area networks (LPWANs). The nodes can be battery powered, and the lifetime of the battery is about ten years, plus they transmit data in small amounts over long distances and a few times per hour (for example, every ten minutes), thus enhancing the battery stamina. LoRa-based environmental sensing system enables farmers to remotely monitor the status of a large farm in near real-time. On the other hand, coverage is highly dependent on obstructions (buildings, trees, hills), environment (heavy rain) and technical factors (high-level radio interference, antenna type), so it is necessary to design the system deployment correctly to achieve full performance [1, 3, 7–9].

1.2 Camelina Culture

An example of the use of LoRa sensors in precision agriculture is the CAMEVAR project of the CAMELINA Operational Group (OG), which focuses on the cultivation of *Camelina sativa* (L.) Crantz. Oil crops such as camelina are one of the major plant groups with the highest production, research, experimentation and marketing worldwide. They are very useful and generate seeds with a high percentage of fatty acids and proteins of high quality that can be used in the chemical, pharmaceutical, cosmetic or animal and human food industries, among others. Its fruit is shaped like a small siliqua with 6–16 seeds with an oil content of between 30% and 40% in dry weight. Oil is very rich in alpha-linolenic acid (ALA), omega-3 fatty acids and high levels of gamma-tocopherol (vitamin E) [10–14].

Camelina cultivation stands out for its high resistance to drought and the reduced need for inputs. Therefore, it is an alternative crop when compared with more demanding rainfed crops. Moreover, among other advantages, it can be adapted as a rotation crop in semi-arid and arid rainfed regions, thus minimizing fallow, where other oilseed alternatives are less competitive [15–18]. In addition, it can be used in crop rotations, as it can grow without fertilization by exploiting residual nitrogen (N), phosphorus (P) and potassium (K) in the soil from previous crops [19–22].

The OG, composed by Camelina Company Spain (CCE), IMIDRA, ASAJA and the farmer, Julián Caballero de la Peña, aims to research on the improvement of the varieties of this oil crop in the central Spain area. To this extent, research is carried out on combining traditional cultivation techniques with new technologies such as remote sensing using Sentinel-1 and Sentinel-2 images or crop monitoring using IoT technologies [23, 24].

1.3 Related Works

The selection of LoRa technologies sensors for the CAMEVAR project was due to the ease of its implementation and its proven performance in other experiences, measuring the soil moisture and soil temperature. This kind of IoT networks have a prolonged lifetime at lower cost compared to other sensors due to the optimized sleep time of sensor nodes and less power consumption. In addition, the use of solar-powered features on sensor nodes extends the lifetime of the network. Thus, this kind of LoRa based gateway is demonstrated to solve power problems and cover large areas in agriculture fields [7].

In addition, it is more suitable for battery-powered devices such as the soil moisture sensors. Reliable communication over long distance is possible because of techniques like adaptive data rate, LoRa's chord spread spectrum radio modulation scheme, and gateways that decode data received on multiple channels modulated with different spreading factors. In precision agriculture, LoRa technology provides low-cost low-power communication solution for prolonged monitoring operations [25].

The rest of the paper is organized as follows: Sect. 2 presents the methodology employed to deploy the LoRa sensors network and collect data. Section 3 depicts the raw results gathered from the sensors and the weather station. This data is discussed in Sect. 4. Lastly, the conclusions and future works are presented in Sect. 5.

2 Materials and Methods

We selected a 2.5-hectare plot (plot X), located on Finca El Encín IMIDRA, in the municipality of Alcalá de Henares, Madrid, Spain. On January 23, 2020, we seeded the plot with camelina's V1 variety (provided by CCE). We used a conventional Solà cereal seeding machine, calibrated at a dose of 8 kg/ha to 10 kg/ha. Later, since rainfall was scarce during the germination period, we performed two short irrigations on plot X to boost the growth of the seeds. The plot is technically divided into 5 sectors that have an independent sprinkler irrigation system, which allows differential irrigation of the crop and soil. On February 13, 2020, we installed sensors in each sector to measure soil moisture (sM) and soil conductivity (sC) (at a depth of 5 cm and 30 cm), as well as ambient temperature (T). We placed the LoRa network hub-gateway close to these sensors (<200 m), on the border of the field. Additionally, as a control plot (plot Y), we installed sensors on another camelina rainfed plot 2000 m away from the experimental plot (Fig. 1 and Fig. 2). We gathered information from the sensors every 15 min. The meteorological data was extracted from the weather station located on the farm, which collects daily data on rainfall and maximum and minimum temperatures.

The monitoring system was formed by LoRa wireless nodes, a local gateway with 3G connectivity, and a cloud data server provided by Plantae®.

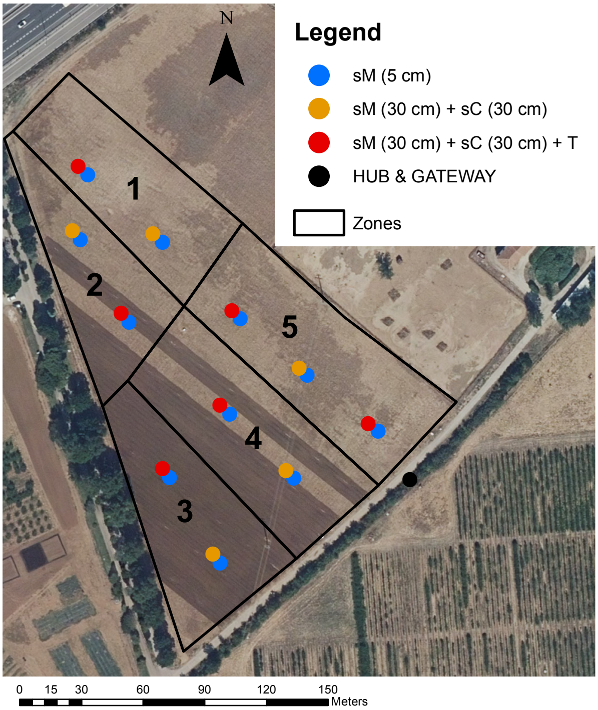

Fig. 1. Sensors and zones distribution in plot X.

The final goal was to perform different stages of irrigation in each sector and to compare the data on soil moisture and conductivity with the rainfed plot. We aimed to assess how the changes in the soil moisture and conductivity took place along with the rainfall or irrigation periods. Thus, even though it is a rainfed crop, we would be able to simulate different rainfall scenarios and evaluate how the soil moisture or conductivity affects the growth and final yield of the camelina.

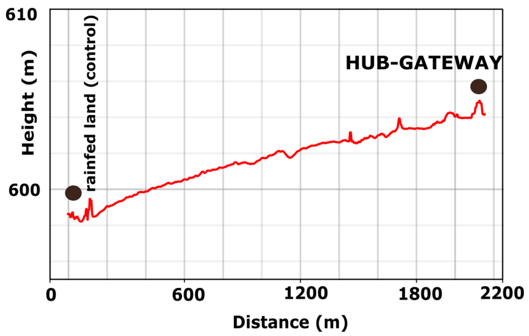

Fig. 2. Average slope between the rainfed control sensor and the hub-gateway.

Unfortunately, because of the COVID 19 situation we were not able to proceed with the differential irrigation calendar in plot X, so all the zones (1 to 5) where rainfed, as in plot Y.

3 Results

In this section, we provide an overview of the data collected by the LoRa sensors and the weather station and explain the possible variables that may have affected the results.

3.1 Meteorological Data

To assess the rainfall and estimate how was its availability for the crop through the infiltration, we processed the meteorological data from the weather station. We calculated the total (68 mm) and diary rainfall (2.16 mm/day), as long with the average temperature since the day we sowed the camelina crop (11.90 °C).

Rainfall was concentrated in the first weeks after the camelina was seeded and in final weeks, where the crop's water demands are higher because it is growing and developing the fruits and seeds (Fig. 3).

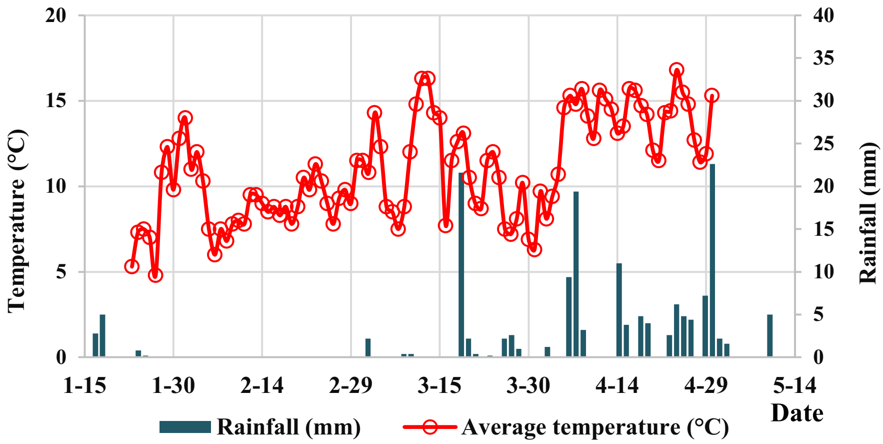

Fig. 3. Finca El Encín weather station (from January 23, 2020, to April 30, 2020).

3.2 LoRa Network Sensors Data

LoRa network sensors gathered data from soil moisture and conductivity along with superficial temperature for plot X and plot Y. We harvested moisture data from the soil at 5 cm and 30 cm. Therefore, there are differences in the variation of soil moisture mainly due to the amount of rainfall and speed of water infiltration through the soil. On the other hand, conductivity remains quite constant, as it was gathered at 30 cm (Fig. 4 and Fig. 5).

In both plots (X and Y) conductivity values at 30 cm are related to moisture at 30 cm, as it is calculated through electrical conductivity variability within the sensor probes, so the graphical representation has certain correlation.

Although the two plots were finally rainfed, because we were unable to apply differential irrigation to plot X, the plot Y "rainfed" sensor showed a remarkable decrease in conductivity. Probably due to the installation method or differences in the soil composition (Fig. 5).

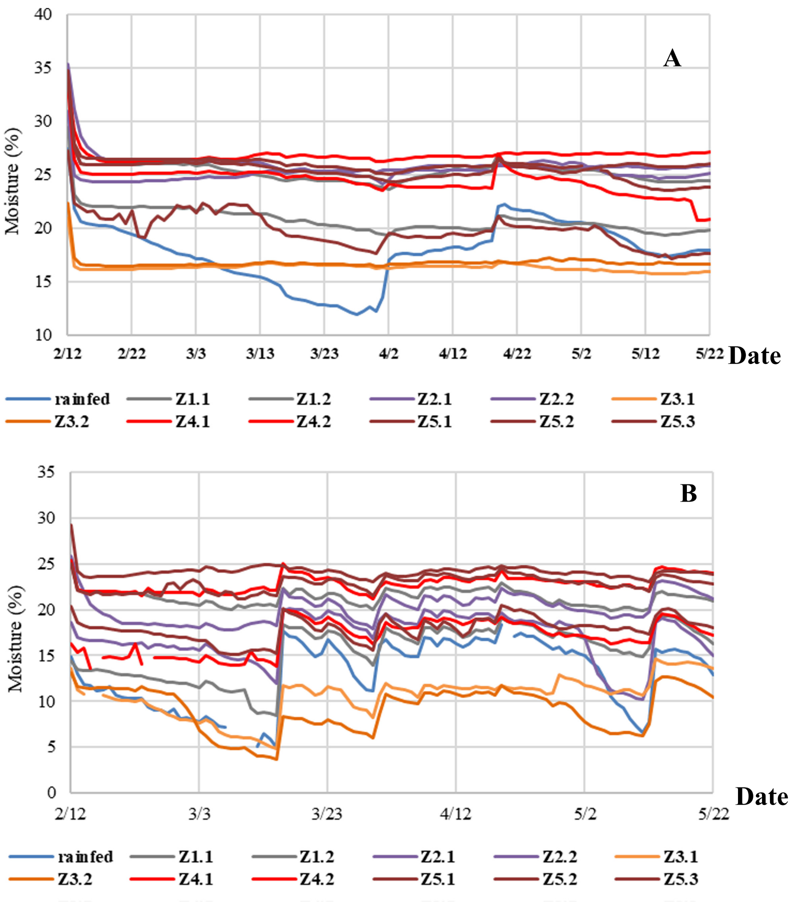

Fig. 4. Soil moisture (HR %) at 30 cm (A) and 5 cm (B).

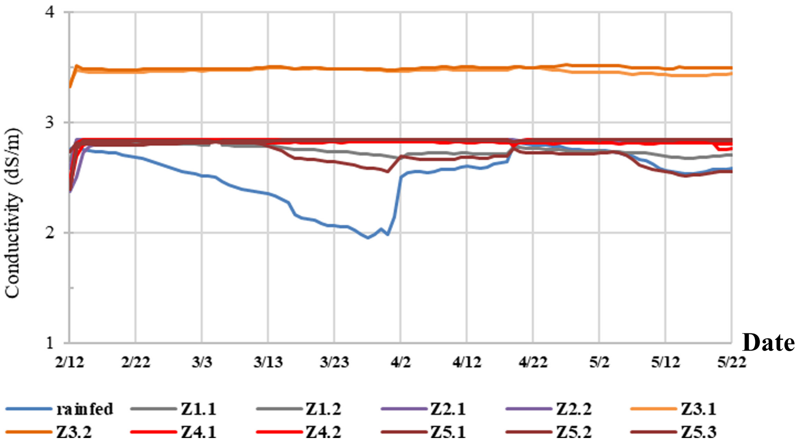

Fig. 5. Soil conductivity (dS/m) at 30 cm.

4 Discussion

Camelina crop is a rainfed culture, thus it only needs rainwater as input, and it is enough to make the crop grow healthy and profitable. In this situation, as OG CAMELINA works to research in best camelina varieties, we wanted to test the behavior of V1 variety in different irrigation scenarios, to simulate several rainfall areas. However, because of the COVID 19 situation we were not able to proceed with the differential irrigation calendar, so all the zones (1 to 5) from plot X where rainfed. This is the reason why the graphs do not show differences in terms of soil moisture, and have a similar behavior. The collected data is based only on the water provided by the rain. Even so, some interesting patterns appear, that may help in understanding soil and crop behavior.

The graphs plot shows how the sensors effectively and quickly detect the increase of moisture in soil at 5 cm because of rainwater; although some differences are appreciated related to the soil texture or the placement of the sensors. In addition, intraday variations in soil moisture are shown because of the day-night cycle, solar radiation and temperature variations.

If this was a conventional irrigation process with sprinklers, this information would allow the farmer to determine when the water begins to infiltrate and is already available for the roots. Every time a rainfall is recorded, there is an increase in the soil moisture at 5 cm, but not at 30 cm. This only happens when rain exceeds certain threshold. Furthermore, there are no significant variations in the soil conductivity, so there is no water infiltration generating soil washing.

Therefore, the rain regime in this central Spain area is not generating water infiltration since moisture is retained in the soil or being used by camelina crop and it is enough for the crop to grow. This fact is important for a rainfed crop like camelina, as we can be sure that the water needs of the plant are fully covered.

Water management is paramount in countries with water scarcity like Spain. This also affects agriculture, as a large amount of water is dedicated to this use. The rising concerns about global warming have led to the consideration of creating water management measures to ensure the availability of water for food production and consumption. Thus, the researches on water usage reduction for irrigation have increased over the years [26]. Therefore, the deployment of cheap LoRa sensors has proven to be a useful system of controlling and managing irrigated crops, but it is also a convenient way to manage rainfed crops to guarantee the yield of the crop or foresee future problems in the development of the plant.

Also, as the future of precision agriculture lies upon modern technological advancements, different kind of smart sensors and remote sensing techniques using Unmanned Aerial Vehicles (UAV), profitability in production farming depends on making correct and timely operational decisions based on current conditions and historical data [27, 28]. Precision agriculture is a comprehensive system designed to optimize agricultural production by carefully tailoring soil and crop management to correspond to the unique conditions found in each field while maintaining environmental quality [28].

5 Conclusions

The use of LoRa sensors for estimating soil moisture and conductivity proves to be a cheap and effective tool as it provides real-time data. This allows the farmer to make decisions about his crop that can be fundamental for its good development and productivity. The installation of a pool of sensors below and under the plants root makes it possible to assess when it is necessary to stop irrigation. If irrigation keeps flowing when moisture increases below the roots, we would be losing water, fertilizers and money.

Gathering data every 15 min in a rainfed field has proven to be enough to understand the behavior of the soil and moisture as a large amount of information is provided. Therefore, increasing the threshold to 1–2 h would not be a problem in rainfed systems were the speed of the physical changes (temperature, moisture, conductivity) is slow.

Although the use of LoRa sensors is more common in irrigated crops of high economic value and yield, the use of cheap sensors in rainfed agriculture can be a great contribution to manage the crop and add additional value to the production. It could provide information on the water needs of the crop and be decisive in assessing whether, in large areas of dry land, it will be economically profitable to cultivate.

As a future work, we aim to install sensors in upcoming rainfed camelina plantations, alternating different varieties of plants and soil management. Therefore, we will be able to gather data on the variation of soil moisture and the final crop yield.

Acknowledgements. PDR18-CAMEVAR project is co-founded by the European Union through the European Agricultural Fund for Rural Development (EAFRD) - Europe invests in rural areas, MAPAMA and the Community of Madrid through IMIDRA, within the framework of the PDR-CM 2014–2020 call.

References

1. Seneviratne, P.: Introduction to LoRa and LoRaWAN. In: Beginning LoRa Radio Networks with Arduino. Apress, Berkeley, CA (2019). https://doi.org/10.1007/978-1-4842-4357-2_1

2. Stočes, M., Vaněk, J., Masner, J., Pavlík, J.: Internet of Things (IoT) in agriculture - selected aspects. Agris On-line Pap. Econ. Inform. **8**, 83–88 (2016). https://doi.org/10.7160/aol.2016.080108
3. Ji, M., Yoon, J., Choo, J., et al.: LoRa-based visual monitoring scheme for agriculture IoT. In: SAS 2019 - 2019 IEEE Sensors Applications Symposium Conference Proceedings, pp. 1–6 (2019). https://doi.org/10.1109/SAS.2019.8706100
4. Ray, P.P.: Internet of things for smart agriculture: technologies, practices and future direction. J. Ambient Intell. Smart Environ. **9**, 395–420 (2017). https://doi.org/10.3233/AIS-170440
5. Gluhak, A., Krco, S., Nati, M., et al.: A survey on facilities for experimental internet of things research. IEEE Commun. Mag. **49**, 58–67 (2011). https://doi.org/10.1109/MCOM.2011.6069710
6. Jazayeri, M., Liang, S., Huang, C.-Y.: Implementation and evaluation of four interoperable open standards for the Internet of Things. Sensors **15**, 24343–24373 (2015). https://doi.org/10.3390/s150924343
7. Heble, S., Kumar, A., Prasad, K.V.V.D., et al.: A low power IoT network for smart agriculture. In: IEEE World Forum Internet Things, WF-IoT 2018 – Proceedings, January 2018, pp. 609–614 (2018). https://doi.org/10.1109/WF-IoT.2018.8355152
8. Mekala, M.S., Viswanathan, P.: A survey: smart agriculture IoT with cloud computing. In: International Conference on Microelectronic Devices, Circuits and Systems (ICMDCS), pp. pp. 1–7. IEEE (2017)
9. Nguyen Gia, T., Qingqing, L., Peña Queralta, J., et al.: Edge AI in smart farming IoT: CNNs at the edge and fog computing with LoRa. In: IEEE AFRICON-2019 (2019)
10. Imbrea, F., Jurcoane, S., Hălmăjan, H.V., et al.: Camelina sativa: a new source of vegetal oils. Rom. Biotechnol. Lett. **16**, 6263–6270 (2011)
11. Zubr, J.: Oil-seed crop: Camelina sativa. Ind. Crops Prod. **6**, 113–119 (1997). https://doi.org/10.1016/S0926-6690(96)00203-8
12. Berti, M., Wilckens, R., Fischer, S., et al.: Seeding date influence on camelina seed yield, yield components, and oil content in Chile. Ind. Crops Prod. **34**, 1358–1365 (2011). https://doi.org/10.1016/j.indcrop.2010.12.008
13. Pilgeram, A.L., Sands, D.C., Boss, D., et al.: Camelina sativa, A Montana Omega-3 and Fuel Crop. In: Proceedings Sixth National Symposium Creating Markets for Economic Development of New Crops and New Uses, pp. 129–131 (2007)
14. Usher, S., Haslam, R.P., Ruiz-Lopez, N., et al.: Field trial evaluation of the accumulation of omega-3 long chain polyunsaturated fatty acids in transgenic Camelina sativa: making fish oil substitutes in plants. Metab. Eng. Commun. **2**, 93–98 (2015). https://doi.org/10.1016/j.meteno.2015.04.002
15. Zanetti, F., Eynck, C., Christou, M., et al.: Agronomic performance and seed quality attributes of Camelina (Camelina sativa L. crantz) in multi-environment trials across Europe and Canada. Ind. Crops Prod. **107**, 602–608 (2017). https://doi.org/10.1016/j.indcrop.2017.06.022
16. Zanetti, F., Monti, A., Berti, M.T.: Challenges and opportunities for new industrial oilseed crops in EU-27: a review. Ind. Crops Prod. **50**, 580–595 (2013). https://doi.org/10.1016/j.indcrop.2013.08.030
17. Dobre, P., Jurcoane, Ş.T.: Camelina crop - opportunities for a sustainable agriculture. Scientific Papers, UASVM Bucharest LIV, pp. 420–424 (2011)
18. Guy, S.O., Wysocki, D.J., Schillinger, W.F., et al.: Camelina: adaptation and performance of genotypes. Field Crop Res. **155**, 224–232 (2014). https://doi.org/10.1016/j.fcr.2013.09.002
19. de Imperial, M., Hornedo, R., Martín Sánchez, J.V., Lobo Bedmar, M. del C., et al.: Respuesta del rendimiento biológico y agrícola de plantas de Camelina (Camelina sativa) y del contenido de proteína y aceite de sus granos al afecto residual de la fertilización orgánica y mineral. Rev Int Contam Ambient **31**, 377–387 (2015)

20. del Mar Delgado, M. Lobo, C., Plaza, A., et al.: Efecto residual provocado por dos lodos de depuradora procedentes de un ensayo de fitorremediación con cardo en un cultivo de camelina (Camelina sativa (L.) Crantz) en Madrid. Rev la Fac Ciencias Agrar **48**, 13–30 (2016)
21. Moore, A., Wysocki, D., Chastain, T., et al.: Camelina Nutrient Management Guide for the Pacific Northwest. Pacific Northwest Ext (2019)
22. McVay, K.A., Lamb, P.F.: Camelina Production in Montana (Report). Bull MT200701AG 8 (2008)
23. Parra, M., Parra, L., Mostaza-Colado, D., et al.: Using satellite imagery and vegetation indices to monitor and quantify the performance of different varieties of Camelina Sativa. In: GEO-Processing 2020: The Twelfth International Conference on Advanced Geographic Information Systems, Applications, and Services Using, pp 42–47 (2020)
24. Mostaza-Colado, D., Mauri Ablanque, P.V., Capuano, A.: Assessing the yield of a multi-varieties crop of Camelina sativa (L.) Crantz through NDVI remote sensing. In: 2019 Sixth International Conference on Internet of Things: Systems, Management and Security (IOTSMS), pp. 596–602. IEEE (2019)
25. Vuran, M.C., Salam, A., Wong, R., Irmak, S.: Internet of underground things in precision agriculture: architecture and technology aspects. Ad Hoc Netw. **81**, 160–173 (2018). https://doi.org/10.1016/j.adhoc.2018.07.017
26. García, L., Parra, L., Jimenez, J.M., et al.: IoT-based smart irrigation systems: an overview on the recent trends on sensors and IoT systems for irrigation in precision agriculture. Sensors (Switzerland) **20** (2020). https://doi.org/10.3390/s20041042
27. Triantafyllou, A., Sarigiannidis, P., Bibi, S.: Precision agriculture: a remote sensing monitoring system architecture. Information **10** (2019). https://doi.org/10.3390/info10110348
28. Gsangaya, K.R., Hajjaj, S.S.H., Sultan, M.T.H., Hua, L.S.: Portable, wireless, and effective internet of things-based sensors for precision agriculture. Int. J. Environ. Sci. Technol. **17**(9), 3901–3916 (2020). https://doi.org/10.1007/s13762-020-02737-6