

Challenges of ecocentric sustainable development in agriculture with special regard to the internet of things (IoT), an ICT perspective

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ABSTRACT

“Feed the global population and regenerate the planet.”

The conditions necessary for the implementation of the above commonly used slogan did not exist 10–15 years ago. We did not have access to the information and databases that would have allowed us to increase yields for the purpose of feeding the growing population. While increasingly meeting sustainability requirements and regenerating the Earth. Anthropocentrism, the belief that humans are superior to everything else, benefits humans by exploiting human greed and ignorance, which is a dead end for both individuals and societies. Only humans can ignore the dynamic equilibrium processes of nature and disregard the consequences that adversely affect future generations. Ecocentric agricultural practices have several prerequisites. It is important for the academic sphere to recognize its significance. Another fundamental challenge is the continuous monitoring of the production unit and its close and distant environment for the purpose of decision preparation using Big Data. The Internet of Things (IoT) is a global infrastructure that represents the network of physical (sensors) and virtual (reality) “things” through interoperable communication protocols. This allows devices to connect and communicate using cloud computing and artificial intelligence, contributing to the integrated optimization of the production system and its environment, considering ecocentric perspectives. This brings us closer to the self-decision-making capability of artificial intelligence, the practice of machine-to-machine (M2M) interaction, where human involvement in decision-making is increasingly marginalized. The IoT enables the fusion of

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information provided by deployed wireless sensors, data-gathering mobile robots, drones, and satellites to explore complex ecological relationships in local and global dimensions. Its significance lies, for example, in the prediction of plant protection. The paper introduces small smart data logger robots, including the Unmanned Ground Vehicles (robots) developed by the research team. These can replace sensors deployed in the Wireless Sensor Net (WSN).

KEYWORDS

sustainability, ICT, IOT, precision agriculture, development

1. INTRODUCTION

Feed the population and regenerate the planet: The conditions necessary to implement this commonly used slogan were not met 10–15 years ago. We did not have the data or information that could have simultaneously enabled us to maintain yields, feed the growing population, maintain unchanged profits, increase biodiversity, meet other sustainability requirements more effectively, and regenerate arable land. The artificial intelligence-based PhD thesis conducted at our department in 2006 also concluded that it is essential to increase the size of databases if we want to better understand and enhance natural and agro-ecological systems and their interconnections (Mike-Hegedűs, 2006).

EU expectations: Below we present the EU directives in detail with the aim of highlighting the complexity of the issue. It also becomes apparent that EU authorities do not consider the introduction of modern monitoring and control systems, as there is no mention of their advantages in the various documents. Objectives of organic farming: Producing food by using natural ingredients and processes is the goal of organic farming. Accordingly, organic farming generally has a minimal effect on the environment since it promotes the following: conservation of biodiversity, preservation of regional ecological balances, responsible use of energy and natural resources, improvement of soil fertility, and protection of water quality. Furthermore, organic farming regulations require that producers meet the unique behavioural demands of their animals and promote a high quality of animal welfare.

Organic farming after 2022: Examples of changes made under the new organic rules include: strengthening the control system, which will help to further increase consumer confidence in the EU organics system; new producer regulations that will facilitate small farmers' transition to organic production; new rules on imported organics to ensure that all organic products sold in the EU are of the same standard; a greater range of products can be marketed as organic (ULR1).

A green deal: While this is the ultimate objective, the EU has set a halfway target for 2030, when it hopes to reduce emissions by 55% from 1990 levels. Even while the primary goal of the Green Deal is to reduce global warming and meet climate targets, putting it into practice will have numerous positive effects on the European continent, "[t]his, too, is a decisive point: economic growth, jobs, and better prospects for the next generation if Europe manages to lead the way in 'green' technologies." Energetic aspects: The Fit for 55 packages, in instance, aims to generate 40% of Europe's energy from renewable sources by 2030. Aspects related to agriculture: the program includes goals such implementing labels that emphasize the level of sustainability of products, cutting the usage of fertilizer and pesticides by 20% and 25%, respectively, by 2030. Environmental



protection aspects: Lastly, the Zero Pollution Action Plan, which aims to eliminate all causes of air, water, and soil pollution by 2050, is also a part of the Green Deal. Regulations outside the EU: Naturally, the EU also needs to consider general expectations and requirements. Global social, economic, and environmental transformation are included in the 2030 Agenda for Sustainable Development (Sustainable Development Goals, or SDGs), which was adopted by all United Nations member states in 2015 (Fetting, 2020; Neményi et al., 2022).

Holt et al. (2016) draw attention to the fact that the regulations regarding food raw material production may contradict the interests of the food industry within various EU rules. The contradictions pertain to organic farming. By using life cycle assessment (LCA), it was found that while conventional cultivation performed better per unit of mass (28.10% lower total environmental footprint compared to organic cultivation), organic eggplant cultivation demonstrated better environmental performance per unit area (24.15% lower total environmental footprint compared to conventional cultivation). Due to the usage of chemical pesticides and fertilizers, the conventional system got higher scores in the intermediate impact categories of eutrophication (up to 37.12%) and ecotoxicity (up to 83.00%). This illustrates the requirement for life cycle assessment (LCA) that takes local environmental effects into consideration (Foteinis et al., 2021). We obtain similar results in animal breeding as well. The ecological footprint of conventionally produced milk is smaller per kilogram of mass compared to that of organic milk (Bos et al., 2007). The following table illustrates the principles and practices of regenerative agriculture (Giller et al., 2021; Tan and Kuebbing, 2023) (Table 1).

The implementation methods of the principles and practices indicated in the table are not extensively discussed in various studies. It must be stated that the EU's ideas about transitioning to regenerative farming raise numerous scientific and practical problems (Giller et al., 2021; EASAC, 2022). It is important to emphasize that regenerative farming primarily focuses on enhancing biodiversity and restoring soil conditions.

Strengthening trust in scientific results and professional experiences. Ecological intelligence. According to the authors' opinion, one of the main prerequisites for the widespread adoption of environmentally friendly practices is the establishment of an ecocentric mind-set. What is ecocentric intelligence? EI consists of four pillars: 1. Individuals have the appropriate knowledge to assess whether their actions meet the criteria of sustainable development. 2. Individuals can judge how their actions impact global changes beyond local effects. 3. Individuals can evaluate social (political) ideas, projects, and express their opinions to decision-makers while aiming for cooperation. 4. Individuals strive to participate in events, organizations, and programs where they can expand their experiences and discuss their opinions and experiences related to sustainable ecological development. However, it is also true that the general acceptance of this mind-set should be supported by education (from kindergarten to university), various short-term and long-term social efforts, legislation, etc.

2. THE INTERCONNECTION BETWEEN GENERAL AND AGRO SUSTAINABILITY

The harmony of the pillars of social and agrarian sustainability implies the coordination of multiple complex systems. A commonly accepted definition for social sustainability is the unity of the pillars of social development, economic growth, and environmental protection.



Table 1. List of regenerative agricultural practices, their principles and importance for restoration of soil health and impact on biodiversity, based on Giller et al. (2021) and Tan and Kuebbing (2023)

Practice (from the most studied to the least ones)	Principles	Level of restoration of soil health	Impact on biodiversity loss reversal
Integrated Nutrient Management	Relying more on biological nutrient cycle	High	N/D
Irrigation regime	Encouraging water percolation	High	N/D
Manure	Build soil carbon	High	N/D
Compost	Build soil carbon	High	N/D
Residue management	Relying more on biological nutrient cycle	High	N/D
Tillage regime	Minimize tillage	High	N/D
Biochar	Encouraging water percolation	High	N/D
Crop rotation	Avoid pesticides	Low	High
Shifting cultivation and Fallow	Foster plant diversity	Medium	High
Agroforestry	Sequester Carbon	High	Medium
Cover crops	Maintain soil cover	High	Low
Improved seed variety	Foster plant diversity	Medium	High
Organic farming	Relying more on biological nutrient cycle	High	N/D
Transplanting to direct seeding	Foster plant diversity	Medium	High
Intercropping	Foster plant diversity	Medium	High
Conservation agriculture	Minimize tillage	High	N/D
Rotational grazing, pasture cropping, holistic [Savory] grazing, silvopasture*	Integrate livestock	Medium	N/D

*These appear only in Giller et al. (2021).

This integration needs to be harmonized with the pillars of agricultural sustainability: Genetics (related to cultivated genomes), Environment (covering production units such as fields, gardens, barns, and the food industry, as well as their surroundings), and Sustainable Management (Hatfield and Walthall, 2015), as depicted in Fig. 1. As evident, the environment and nature conservation play a crucial role here. Any significant change in any other pillar, whether positive or negative, typically manifests in the form of environmental changes. The question is what kinds of changes are occurring, how these changes can be detected or indexed, and how the changes in indexes can be monitored (Fig. 2).

3. SUSTAINABLE BIODIVERSITY INDICES (INDICATORS)

Ecosystem functions and services present significant challenges to monitoring and control systems (Purcell, 2018). Herzog et al. (2013) developed a toolkit consisting of 23 indicators, which were tested in 15 European and African regions. The indicator groups were as follows: Three Genetic Diversity Indicators, four Species Diversity Indicators, eight Habitat Diversity Indicators, and eight Farm Management Indicators. IoT applications have emerged. It is worth



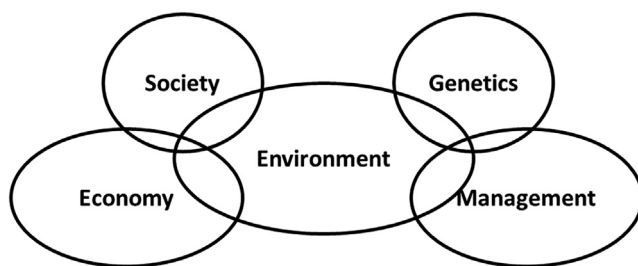


Fig. 1. The general (left) and agricultural sustainability (right) criteria's general interconnection (Own Figure)

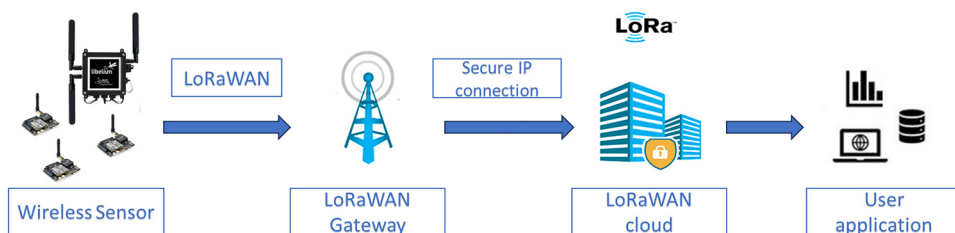


Fig. 2. The General structure of IoTs (Own Figure)

mentioning the Providence IoT system widely used in the Amazon rainforests, which can be adapted for monitoring EU Green Deal expectations (Nay, 2020).

Soil monitoring: The impact of human interventions on the soil can be tracked through monitoring changes in the Soil Degradation Rate (SDR) parameter. This parameter is based on integration of Soil Degradation Rate (SDR), Soil Fertility Index (SFI), Soil Quality Index (SQI), and Soil Resilience Rate (SRR). The interrelationships and conditions of soil parameters (available phosphorus, potassium, and nitrogen, EC, pH, Sp, ESP, CEC, OC, SAR, and CaCO_3) were demonstrated using geo-statistics. Geostatistical mapping of spatial soil variability could lead to precision agriculture applications (AE Abdel Rahman et al., 2022). Seven soil functions have been used in Towards a Thematic Strategy for Soils, and 8 Soil threats according to the Towards a Thematic Strategy for Soils (Jónsson et al., 2016). The integration of proximal: UGV (Unmanned Ground Vehicle), UAV (Unmanned Aerial Vehicle), and satellite soil monitoring offers significant possibilities (Sheffield and Morse-McNabb, 2015).

4. PARADIGM CHANGES IN AGRICULTURE. THE THIRD GREEN REVOLUTION

The first green revolution was pioneered by Norman Borlaug (Mohanta, 2009). Its essence lay in significantly increasing yields through the application of cutting-edge chemicals, fertilizers, propagating materials, and machinery, emphasizing technological discipline. In the early



1990s, the advent of satellite positioning systems enabled the “greening” of the revolution with the emergence of precision technologies]. In 1998, Tilman highlighted the necessity of the greening of the green revolution, emphasizing the introduction of environmentally friendly agricultural technologies and referring to modern precision technologies. We can trace the second green revolution back to the 1990s (Tilman, 1998). The definition of precision farming (PA) according to ISPA (International Society for Precision Agriculture) is: “Precision Agriculture is a management strategy that gathers, processes and analyses temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.” The essence of precision technologies is to divide the arable land into management zones, which are considered homogenous in terms of soil chemical, physical, and biological (microbiological) characteristics, and to determine inputs and treatments in a site-specific manner. These management zones can be as small as a few hundred square meters, but we can also refer to this system as a “per plant” platform.

5. PRECISION AGRICULTURE INTEGRATED WITH IOT: THE MOSONMAGYARÓVÁR AGRO IOT SYSTEM

Since the 2015s, we can speak of the third Green Revolution, which marks the beginning of the integration of IoT and Precision Agriculture (PA). The IERC (IoT European Research Cluster) definition states that IoT is: “A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual ‘things’ have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network.” Smart is a clever system with adaptability. Its implementation requires the processing of digitized databases and Big Data, and it is based on artificial intelligence, while also taking advantage of cloud computing. The literature sources ITU and FAO (2021) and Nyéki et al. (2020) summarize the IoT developments at the Albert Kázmér Agricultural Faculty of the Széchenyi István University.

6. GENERAL STRUCTURE OF IOTS

Mobile (robot UGV) small-smart data logging system development. The stable sensor network exchange for dynamic monitoring and control. According to Wang et al.’s (2019) literature, in addition to the measuring stations already indicated, we are developing a mobile measuring unit, the data of which complements the current data. The robot is a rubber-footed machine with two DC motors that is fixed to a metal frame. A Raspberry Pi 4 microcomputer has been installed in place of the original Raspberry Pi 3 control. It is protected from external influences by a specially designed cover panel that also contains connectors and other extra electronic parts. The robot is based on a three-axis servomotor arm with a servomotor-driven level sampling device at its end. Additionally, it is equipped with an RGB camera that has servomotors that allow it to be positioned along two axes. The device can move autonomously between the crop’s rows due to an ultrasonic distance sensor and a lidar sensor for orientation. It also collects information from the environment, such as global radiation, ambient temperature and humidity, soil surface



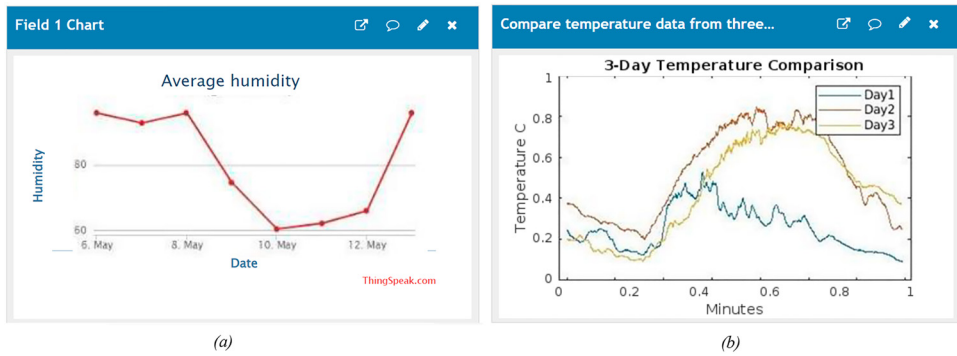
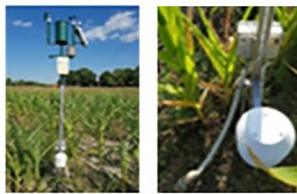


Fig. 3. (a, b) Visualisation of data measured with a self-developed small smart robot (Own Figure)



*Installed sensors in a research crop field, measured parameters :
air temperature, humidity, pressure, CO_2 and ammonia*



air temperature, humidity, wind speed, precipitation and global radiation



soil temperature, EC, moisture, oxygen and stalk diameter

Fig. 4. Installed sensors in Mosonmagyaróvár Agro IoT (Own Figure)



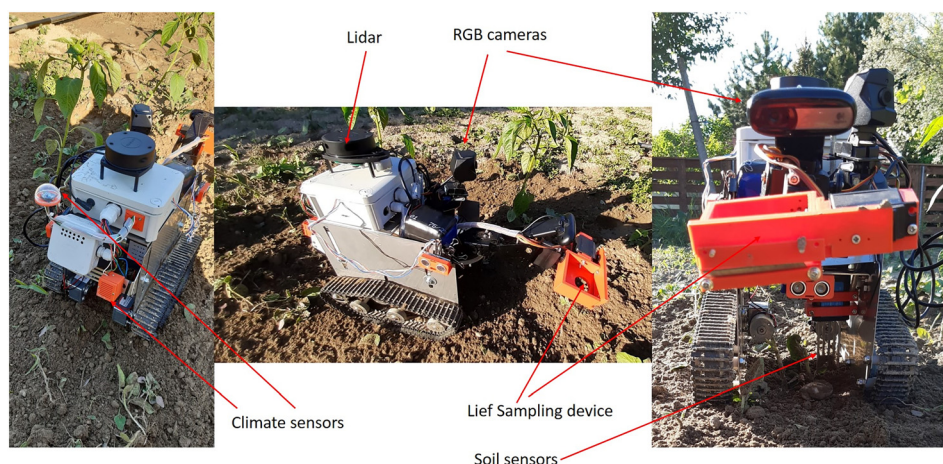


Fig. 5. Architecture of developing a small-smart robot (Own Figure)

temperature, and soil properties (temperature, moisture content, EC, pH, NPK). In the analysis of camera images, artificial intelligence based on a neural network is able to detect changes in plant parts and signal this to the robot operator. The robot's control software is written in the Python programming language. It allows the user to have complete control and optimization of the machine. It is possible to operate the device via both wired (LAN) and wireless (Wi-Fi, Bluetooth) connections (Fig. 3 (a, b), Figs 4 and 5) (Ambrus et al., 2022). The data logger robot is not only suitable for data collection and processing but also for control tasks, collaborating, for example, with advanced cameras (hyperspectral imaging). With this capability, early detection of microbiological infections can be achieved (Bauriegel et al., 2011). The above research can contribute to harmonizing the Lab and the Field measuring results (Pernel, 2017).

7. CONCLUSIONS

We have limited information about the condition for the sustainable coexistence of natural and agricultural ecosystems. The integrated IoT in Precision Agriculture (PA) with small-smart robot data loggers and controllers provides increasing transparency in space and time concerning the food chain and its surrounding environment. This Farm to Fork system not only benefits consumers but also provides valuable information for researchers and managers in improving production processes. Without the small-smart data loggers and controllers working together, such databases would not be available to us. The system, including sensors on drones and satellite data, can continuously expand, accommodating a wider range of biodiversity and soil sustainability indicators. Through AI-based analyses, the size of these databases can be significantly increased (Nyéki A et al., 2022; Nyéki A et al., 2021; Nyéki A and Neményi, 2022). The third Green Revolution enables the broader emergence of ecological intelligence (Goleman, 2010).

Conflict of interest: The first author, Miklós Neményi is a member of the Editorial Board of the journal. Therefore he did not take part in the review process in any capacity and the submission was handled by a different member of the editorial board.



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