ENHANCING RURAL SUSTAINABILITY THROUGH ROBOTICS-ENABLED CORN CULTIVATION IN THE WESTERN PLAIN OF ROMANIA

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RESEARCH ARTICLE

Abstract

The agricultural sector is facing unprecedented challenges in meeting the global demand for food while ensuring sustainability and efficiency. The advent of precision agriculture methodologies, combined with innovative technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, Cloud computing, and robotics, has led to the emergence of Farming 4.0 solutions. These technological advancements have revolutionized farming, enabling a more efficient, precise, and sustainable approach to food production.
One key technology that has emerged as a critical component of Farming 4.0 is robotics. Robots in agriculture can revolutionize the industry, enabling the automation of various tasks, such as planting, monitoring, and harvesting crops. They can also analyze data to provide insights that help farmers make better decisions. Robotics in agriculture has several advantages, including increased productivity, reduced labor costs, and improved yields. Furthermore, robots can work in hazardous conditions unsuitable for human labor, reducing the risk of injury and enhancing safety. This paper provides an overview of the use of robots in agricultural machines and outlines their future direction in corn cultivation technology in the Western Plain of Romania. Based on selection criteria specific to the area, a set of robots has been identified that can be recommended for corn cultivation technology, particularly for organic crops. The results of this study demonstrate the significant potential of robotics in agriculture to enhance the production process and ensure sustainable food production.

Keywords: Farming 4.0, IoT, precision agriculture, robots for agriculture.
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INTRODUCTION

The contemporary agricultural landscape is confronted with unprecedented challenges arising from rapid population expansion, environmental degradation, and the intricacies of global food systems. Regulatory bodies and stakeholders globally are increasingly embracing innovative solutions, mainly digital and robotic technologies, to revolutionize agricultural practices and ensure food security.

Projections estimate that the world's population will approach 8.5 billion by 2030 and increase by 1.18 billion in the subsequent two decades, reaching 9.7 billion by 2050 (United Nations, 2022). Satisfying the dietary needs of this growing population demands an increase in food production by 59-98 percent. This gradual growth trajectory underscores the pivotal role of leveraging technological innovations such as artificial intelligence (AI) and robotics to bolster agricultural sustainability and address the evolving demands of an expanding populace.

Agriculture is currently experiencing what is known as the ”Digital Revolution.” This presents a significant opportunity to improve the lives and livelihoods of farmers worldwide. The UNDP's "Precision Agriculture for Smallholder Farmers" initiative aims to explain and contextualize the emerging innovative digital farming technologies (UNDP, 2021). This initiative focuses on smallholder farmers in developing countries, providing an overview of the data-driven farming technologies driving the digital revolution. The initiative also highlights the primary challenges that hinder the widespread adoption of these technologies and provides recommendations and important considerations to overcome these obstacles.

The agricultural industry has been actively embracing various forms of robotic technology to enhance productivity while minimizing costs. Automated tractors and combines guided by GPS have been widely adopted for precision agriculture, aiming to optimize resource usage. Additionally, there is a growing experimental utilization of autonomous systems for tasks including pruning, thinning, mowing, spraying, and weeding (European Commission, 2021). Sensor technology plays a crucial role in managing pests and diseases that impact crop yields.

Concurrently, digital technologies are progressively improving the affordability and accessibility of precision agriculture solutions, extending their benefits to smallholder farmers in developing nations. These advancements encompass remote sensing methodologies facilitated by satellites and unmanned aerial vehicles (UAVs), as well as the integration of sensors and Internet of Things (IoT) technologies. Moreover, agricultural robots leverage variable rate technology to optimize resource usage and enhance productivity. These technological advancements are underpinned by developments in data processing and analytics, including the utilization of machine learning (ML) algorithms. Such applications are pivotal in fostering sustainability and promoting organic agricultural production, thereby contributing to the production of healthy food.

Prominent regulatory bodies across the globe, Australia included, are proactively engaging in comprehensive initiatives aimed at implementing sustainable AI-driven technologies. These efforts encompass a wide range of strategic measures and policy frameworks designed to foster the development, deployment, and utilization of AI robotics in a manner that prioritizes environmental sustainability, social responsibility, and ethical considerations.

The "Digital Foundations for Agriculture Strategy," crafted by the Australian Government's Department of Agriculture Water, and the Environment, encompasses a holistic approach aimed at revolutionizing the Australian agricultural sector through the integration of cutting-edge AI and robotics technologies. The primary objective is to ensure the sustainability and competitiveness of the agricultural market while promoting organic and environmentally friendly practices. The strategy recognizes the significant impact of farm machinery automation on operational efficiency and reliance on manual labor while also highlighting the importance of edge-of-field monitoring technologies in documenting the quality of runoff water on farms, reducing costs, and enabling targeted improvements to environmental management practices (Australian Government, 2022).

In addition, the strategy emphasizes the enhanced functionality of satellite technology for remote monitoring of agricultural activities. This includes measuring field areas, identifying crop types, assessing groundcover percentage, geolocating landscape features, and evaluating environmental impacts, all of which are essential for informed decision-making and sustainable land management. Traceability and digital logistics services play a crucial role in streamlining agrifood supply chains, providing transparent and trustworthy information to consumers, producers, and other stakeholders. Robotics technology such as drone farming and intelligent livestock monitoring technologies contribute to cost-effective remote monitoring and early disease detection, improving animal welfare and overall farm productivity. Soil carbon sequestration initiatives are also recognized as having significant potential to improve farm productivity, enhance resilience to climate change, and create new market opportunities for land managers (Australian Government, 2022).

Additional initiatives by the Australian Government aimed at fostering sustainable agricultural practices are delineated in the "National Agricultural Statement Innovation Policy" (Australian Government, 2021) and CSIRO's analysis on "The Future of Australia's Agricultural Workforce" (CSIRO, 2019). These documents underscore the government's commitment to leveraging robotics and artificial intelligence (AI) technologies to advance the sustainability agenda in agriculture.

This research endeavor delves into the feasibility of incorporating AI-powered robotic solutions in corn cultivation to foster sustainability within the rural regions of the Western Plain of Romania. By conducting a comprehensive examination of the regulatory framework and successful deployment of robotic solutions in agriculture across diverse geographical regions, this study aims to offer valuable insights to policymakers, stakeholders, and practitioners regarding the advantages and obstacles associated with integrating AI-enabled robotics in agricultural contexts. The research methodology employed encompasses empirical analysis and case studies, drawing upon data sourced from farmers, agricultural institutions, and government agencies. Additionally, a central tenet of this study is the advocacy for responsible and sustainable deployment practices of AI and robotics in agriculture.

MATERIAL AND METHOD

The study was initiated by thoroughly examining the global agricultural robotics market to identify optimal solutions for fostering organic corn cultivation in the Western Plain of Romania. Companies such as Naïo Technologies, AGROINTELLI, AGXEED, Digital workbench, Softivert, EarthAutomations, AutoAgri, Oxin, SwarmFarm were meticulously examined for their multifunctional robotics offerings, encompassing models such as Naïo Technologies' Orio and Oz, AGROINTELLI's ROBOTTI LR, AGXEED's AgBot 5.115T2 and AgBot 2.055W4, Digital workbench's Tipard 1800, Softivert's SoftiRover e-K18, EarthAutomations's Dood, AutoAgri's ICS20, Oxin's Smart Machine and SwarmFarm's SwarmBot, are proficient in executing diverse tasks ranging from soil preparation to weeding and early-stage plant management. Moreover, specialized solutions focusing on weed control were explored from Pixelfarming, Hari Tech, Carré, FarmWise, Kilter, Solinftec, Andela, Hari Tech, Exobotix, FarmDroid, Carbon Robotics, Aigro and Ekobot, while companies like FieldRobotics, Monarch, Sitia's TREKTOR and Amos underwent evaluation for their autonomous tractor solutions. In this context, we also explored the capabilities of the H.S.S. AgBot 2.055W3 + CF2000-AB, Jacto's Arbus 4000 JAV, Robotics Plus's Prospr and GUSS for the fertilization process, alongside the Small Robot Co's Tom v4 and XAG R150 for the process of crop monitoring. Noteworthy was the innovative all-in-one solution from NEXAT, engineered to oversee all aspects of sunflower cultivation. The study also considered emerging projects such as Ecorobotix's AVO spraying robot, Nexus's weeding solutions, Rowbot's fertilizing robot and Bluewhite company's autonomous tractor endeavor. Furthermore, attention was devoted to solutions facilitating data collection, exemplified by TERRA-MEPP's TerraSentia robot, Digital workbench's Tipard 350 and DJI's Mavic 3M, with the aim of enhancing precision agriculture practices.

Simultaneously an exhaustive exploration was conducted into sustainability policies within the agricultural domain, with a specific emphasis on the European Union (EU). This analysis included the development of a sustainable bioenergy policy tailored for the EU post-2020, stressing the imperative need to promote the efficient and sustainable utilization of organic biomass resources for bioenergy production (CEMA, 2016). Key considerations within this policy formulation encompassed climate and energy targets.

Additionally, the study incorporated compliance with the European Organic Farming Regulation, mandating adherence to stringent organic farming standards (European Parliament, 2018) while also adopting FAO's endorsement for best practices aimed at advancing the Sustainable Development Goals (SDGs) (FAO, 2020). Insights from the Position Paper on EU Carbon Farming underscored the pivotal role of intelligent agricultural machinery in advancing organic carbon farming methodologies, advocating for policy measures and technology adoption to facilitate sustainable organic corn cultivation (CEMA, 2024). The research also incorporates insights from IFOAM on organic farming and biodiversity, addressing increased biodiversity abundance and richness across habitats and farming types, positive impacts on soil microbial diversity, and the adoption of biodiversity-enhancing practices like mixed farming systems and diverse rotations (IFOAM, 2020).

Furthermore, in pursuit of achieving self-sufficient energy and mitigating carbon emissions, the designated cultivation farm implemented a biogas generator harnessing onsite organic waste for electricity generation and power for high-capacity agricultural machinery, particularly for crop transportation. Aligned with these sustainability objectives, all farm infrastructure will be equipped with a photovoltaic panel system for energy generation, complemented by energy storage capabilities, thereby further reinforcing sustainable practices within the agricultural framework.

RESULTS AND DISCUSSIONS

In this segment, we conduct a thorough investigation into the practical consequences and contextual complexities linked to incorporating robotic technologies into the methods of cultivating corn, particularly focusing on the agricultural settings of the Western Plain of Romania. The chapter presents a multi-dimensional exploration into the various aspects of robotic involvement throughout different stages of corn farming. It is distinguished by a meticulous examination of their operational subtleties, and environmental impacts, thus providing deep understanding into how robotics could revolutionize agricultural practices.

Robots for Data Collection

Before initiating any cultivation procedures, it's imperative to gather essential data crucial for training the robotic systems. This data acquisition process involves the utilization of Unmanned Aerial Vehicles (UAVs) such as the DJI Mavic 3M (https://ag.dji.com/mavic3m?site =ag&from=nav) for aerial mapping of the designated area. These UAVs enable comprehensive aerial surveys, providing crucial insights into the terrain and environmental factors that influence cultivation (Figure 1).

Figure 1 **DJI's Mavic 3M area mapping drone** (https://ag.dji.com/)

Additionally, ground-level data collection is facilitated by field robots like the TerraSentia (https://www.earthsense.co/terrasentia),or Tipard 350 (https://digital-workbench.de/en/ portfolio-item/tipard-350/).

These robots traverse through the fields, gathering detailed information about soil composition, moisture levels, and other pertinent parameters. When equipped with swarm capabilities, TerraSentia robots can collaborate and operate in groups, allowing them to cover larger areas more efficiently and collect data from diverse locations simultaneously (Figure 2).

By employing both aerial and ground-based technologies, a holistic dataset is obtained, ensuring the robots are equipped with accurate and comprehensive information essential for optimizing cultivation processes. This collaborative approach not only enhances the speed and scope of data gathering but also improves the robustness and reliability of the collected data, ultimately leading to more informed decision-making and more effective agricultural management practices. Furthermore, this data collection process allows for the identification of potential challenges such as weed infestations and disease outbreaks. By analyzing the gathered data, one can anticipate the types of weeds that might proliferate in the area and the diseases that crops are susceptible to. Armed with this knowledge, farmers can implement targeted strategies for weed control and disease management, minimizing yield losses and promoting crop health. Moreover, leveraging the collected data, digital twin training of the robots can be conducted before even setting foot in the field. Digital twins are virtual replicas of physical assets or processes, in this case, the agricultural environment. By simulating various scenarios based on the gathered data, the robots can undergo extensive training in a virtual environment, honing their capabilities and refining their algorithms to navigate and operate efficiently in the real-world field conditions. This proactive approach to training ensures that the robots are well-prepared and optimized for the specific challenges and dynamics of the agricultural landscape, maximizing their effectiveness and productivity from the outset.

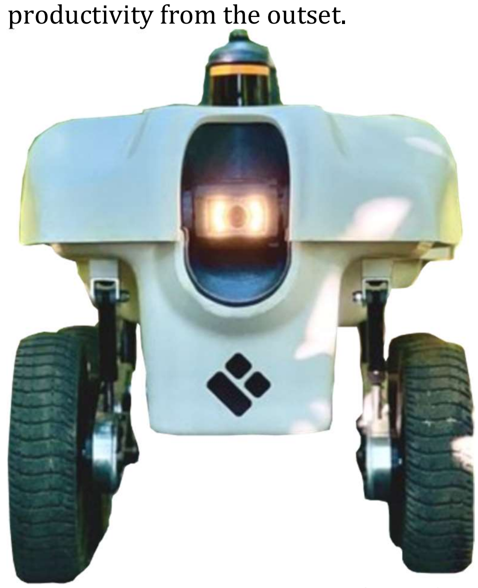

Figure 2 **TERRA-MEPP's TerraSentia field robot** (https://www.earthsense.co/)

Importantly, integrating robotic technologies into agriculture not only enhances productivity and efficiency but also contributes to sustainability efforts. By precisely targeting inputs such as water, fertilizers, and pesticides based on real-time data and predictive analytics, robotic systems help minimize resource wastage and environmental impact, promoting more sustainable farming practices for the future.

Robots for Soil Preparation

The utilization of robotic technologies, spearheaded by companies such as Naïo Technologies (https://www.naio-technologies. com/en/home/), AGROINTELLI (https://agro intelli.com/), AGXEE (https://www.agxeed.com /), Digital Workbench (https://digitalwork bench.de/en/home-2022/), Softivert (https:// www.preciagri.com/), Earth Automations (https ://www.Earthautomations.com/homeen/), Auto Agri (https://autoagri.no/), Oxin (https:

//www.oxin.nz/), and SwarmFarm (https://www.swarmfarm.com/), has revolutionized the soil preparation process in corn cultivation. Notable robotic systems in this domain include Naïo Technologies' Orio and Oz, AGROINTELLI's ROBOTTI LR, AGXEED's AgBot 5.115T2 and AgBot 2.055W4, Digital Workbench's Tipard 1800, Softivert's SoftiRover e-K18, EarthAutomations's Dood, AutoAgri's ICS20, Oxin's Smart Machine, and SwarmFarm's SwarmBot. These sophisticated machines are pivotal in optimizing agricultural efficiency, sustainability, and productivity.

The rationale behind employing these robotic systems stems from their remarkable capability to execute precise and repetitive tasks with minimal human intervention. Such precision not only diminishes labor expenses but also mitigates adverse effects like soil compaction and erosion, thereby fostering enhanced soil health and bolstering crop yields. Furthermore, these robots are endowed with advanced sensing and navigation systems, enabling them to operate autonomously amidst the intricacies of dynamic agricultural environments.

In the soil preparation process for corn cultivation, these robotic systems collaborate harmoniously with precision implements from MONOSEM and PÖTTINGER, premier manufacturers of agricultural equipment known for their commitment to sustainable farming practices. Specifically, implements such as precision min-till or no-till cultivators are seamlessly integrated with the robots, facilitating meticulous soil cultivation tailored to the specific requisites of corn cultivation without disturbing the soil structure. This meticulous approach ensures optimal plant spacing, uniform soil structure, and effective weed control, culminating in maximized crop growth and yield potential while minimizing soil disturbance. By employing no-till practices, these precision implements preserve soil health by reducing erosion, maintaining soil moisture, and retaining organic matter. Additionally, the integration of no-till practices into the robotic soil preparation process reduces fuel consumption and greenhouse gas emissions associated with conventional tillage operations, further enhancing the sustainability of corn cultivation. Thus, the seamless integration of robotic systems with precision implements, particularly those designed for no-till practices, represents a comprehensive approach to soil preparation for corn cultivation that optimizes both productivity and environmental stewardship.

In the context of soil preparation for corn cultivation, the integration of swarm robotics and digital twin training further solidifies the sustainable and efficient practices enabled by robotic systems. Notable examples from the list of robots mentioned earlier, such as Naïo Technologies' Orio and Oz, AGROINTELLI's ROBOTTI LR, AGXEED's AgBot 5.115T2 and AgBot 2.055W4, and SwarmFarm's SwarmBot (Figure 3), exemplify the advancements in this field. Swarm robotics, a concept where multiple robots operate collaboratively in coordinated groups, significantly enhances the efficacy of soil preparation processes. These robots work in unison to cover larger expanses more efficiently, expediting task completion while minimizing energy consumption. By distributing tasks among multiple units, swarm robotics optimizes resource utilization and reduces the overall environmental footprint of agricultural operations.

Figure 3 **SwarmFarm's SwarmBot multipurposed robot** (https://www.swarmfarm.com/)

Moreover, this collaborative paradigm enhances system resilience, as the failure of individual units does not disrupt the overall workflow, ensuring continuous operation even in the face of technical issues or obstacles. Furthermore, the integration of digital twin training enhances the precision and effectiveness of soil preparation activities. This proactive approach ensures that robots are well-prepared and optimized for the specific challenges and dynamics of soil preparation for corn cultivation.

Together, the integration of swarm robotics and digital twin training, exemplified by robots such as Naïo Technologies' Orio and Oz, AGROINTELLI's ROBOTTI LR, AGXEED's AgBot 5.115T2 and AgBot 2.055W4, and SwarmFarm's SwarmBot, augments the efficiency and sustainability of robotic soil preparation processes for corn cultivation. By leveraging collaborative robotics and advanced simulation techniques, agricultural operations can achieve higher productivity levels while minimizing environmental impact, thus fostering long-term sustainability and resilience in agricultural systems. Additionally, the strategic use of photovoltaic panels for harnessing solar energy further reduces reliance on fossil fuels, mitigating carbon emissions and aligning with sustainable farming practices.

Robots for Seeding

In the realm of corn seeding, robotics play a pivotal role in enhancing efficiency and precision. Alongside Naïo Technologies' Orio and Oz, AGROINTELLI's ROBOTTI LR, and AGXEED's AgBot 5.115T2 and AgBot 2.055W4, several other robots and implements contribute significantly to the process.

Digital Workbench's Tipard 1800 is an autonomous multi-carrier platform meticulously crafted for the seamless automation of entire process chains, with a particular focus on corn seeding within arable farming. This innovative robot is designed to elevate performance, minimize environmental impact, and offer multifunctional versatility, especially in the context of corn cultivation. With its five implement spaces, the Tipard 1800 delivers unparalleled flexibility, allowing for the integration of various implements tailored specifically for corn seeding tasks. One of its standout features lies in its integration of advanced seed metering technology, ensuring precise seed placement while minimizing waste. This capability is paramount in optimizing germination rates and achieving uniform crop emergence, crucial factors for maximizing corn yields. The Tipard 1800's efficiency is further underscored by its ability to cover vast areas with exceptional speed and accuracy. This makes it exceptionally well-suited for large-scale corn seeding operations, where timely planting is essential for optimizing yield potential. Whether it's planting corn in expansive fields or intricate planting configurations, the Tipard 1800 rises to the challenge with unmatched efficiency and precision. Moreover, the Tipard 1800 offers flexibility in its drive train type, with options for both pure electric and diesel-electric configurations. This versatility allows farmers to adapt the robot's operation to suit their specific needs and preferences. Depending on the chosen configuration, the Tipard 1800 can operate purely electrically or as a hybrid vehicle with a diesel generator, providing up to 24 hours of continuous operation. This ensures uninterrupted seeding operations, even in remote or off-grid locations.

Softivert's SoftiRover e-K18 stands out for its versatility and adaptability, embodying a significant leap forward in agricultural technology. Developed by Softivert, a leader in the agricultural technology space, this robot is engineered to optimize large-scale crop production, including corn seeding, among other tasks. Equipped with interchangeable seeding modules, the SoftiRover e-K18 seamlessly transitions between different crops, including corn. This capability reflects the robot's commitment to enhancing efficiency, sustainability, and precision in farming operations. By maintaining precision and consistency in seed placement, the SoftiRover e-K18 ensures optimal conditions for corn germination and emergence, crucial factors in maximizing yield potential. The robot's precision in hoeing and seeding allows for meticulous weed management and optimal seed placement, contributing to improved crop health and productivity. Softivert has a legacy of innovation and sustainability in agricultural technology, consistently pushing the boundaries of what's possible in agricultural automation. The SoftiRover e-K18 is a testament to this commitment, designed to meet the complex demands of modern farming while reducing labor and environmental footprint associated with traditional practices.

AutoAgri's ICS20 is another notable robot designed for corn seeding tasks. With its robust construction and advanced navigation capabilities, the ICS20 can operate effectively in various field conditions, ensuring reliable performance throughout the seeding season. Moreover, the ICS20 integrates an electric drivetrain, enabling it to carry many different implements currently available in the market. This versatility allows farmers to utilize a wide range of seeding implements tailored to their specific needs and preferences. Additionally, AutoAgri recognizes the importance of electrification in future farming practices and is committed to offering both fully electric and plug-in hybrid versions of the ICS20. This dedication to electrification aligns with the industry's shift towards sustainable agriculture, providing farmers with environmentally friendly options to enhance efficiency and productivity in corn seeding operations (Figure 4).

These robots, along with their associated implements, revolutionize the corn seeding process by providing farmers with precise, efficient, and labor-saving solutions. By leveraging automation and robotics, farmers can optimize seed placement, reduce input costs, and maximize yields, contributing to sustainable agriculture practices and food security.

Figure 4 **AutoAgri's ICS20 multipurposed robot** (https://autoagri.no/)

Robots for Phytosanitary Treatments and Fertilizer Application

For the phytosanitary treatments and fertilizer application in corn cultivation, sustainability takes center stage with innovative robotic solutions such as the H.S.S. AgBot 2.055W3+CF2000-AB (https://holspraying systems.com/), Jacto's Arbus 4000 JAV (https:/ /jacto.com/europe) and GUSS (https://gussag .com/) with their cutting-edge technology for precise phytosanitary treatments and fertilizer application.

Moreover, Robotics Plus's Prospr (https:/ /www.roboticsplus.co.nz/) sets a new standard for sustainable fertilizer application in corn cultivation. Utilizing advanced sensing and AI technologies, this robot precisely targets fertilizer application, optimizing nutrient uptake and minimizing waste. Its autonomous operation ensures efficient use of resources, contributing to environmentally responsible farming practices. In the context of corn cultivation, Prospr serves as a pivotal tool, enhancing sustainability and efficiency throughout the fertilizer application process. With its modular architecture, Prospr seamlessly adapts to the dynamic needs of corn fields, rotating multiple tools and attachments to optimize fertilizer application. The platform's autonomous implement carrier capability revolutionizes corn cultivation by offering precise and targeted fertilizer application. Equipped with four quick release couplings and a four-fan Q4 sprayer based on Croplands Quantum technology, Prospr ensures uniform coverage while minimizing chemical usage. Prospr's innovative design includes a pivoting point between the drive unit and the implement, enabling optimal adaptation to varying soil conditions commonly found in corn fields. Additionally, repositioned LiDAR sensors provide side views and blind spot detection, enhancing safety and efficiency during operation. The fully electric drivetrain, powered by a Tier 4 diesel generator, ensures seamless operation across corn fields, optimizing energy usage while minimizing environmental impact. With an approximate range of 24 hours per tank of fuel, Prospr maximizes efficiency throughout the fertilizer application process, contributing to sustainable corn cultivation practices. Prospr's dimensions, turning radius, and spray tank capacity are meticulously designed to meet the specific requirements of corn cultivation. Its precise application rate of 180 liters per 2,680 hectares ensures optimal nutrient distribution, promoting healthy corn growth and maximizing yields.

Figure 5 **Robotics Plus's Prospr spraying robot** (https://www.roboticsplus.co.nz/)

Robots for Weed Elimination

In the dynamic world of corn cultivation, a vibrant spectrum of cutting-edge weeding robots from leading companies like Pixel farming (https://pixelfarmingrobotics.com/), HariTech (https://hari-tech.com/), Carré (https://www. carre.fr/en/), FarmWise (https://farm wise.io/), Kilter (https://www.kiltersystems.com/), Solinftec (https://www.Solinftec.com/ en-us/\), Andela (https://www.andela-tni.nl/en/), Exobotix (https://www.exobotic.com/), FarmDroid (https://farmdroid.com/), Carbon Robotics (https://carbonrobotics.com/), Aigro (https://www.aigro.nl/index_en.html) and Eko bot (https://www.ekobot.se/) are transforming traditional weed management practices. These innovative solutions harmonize advanced robotics, AI algorithms, and precision cultivation techniques to revolutionize weed control while championing environmental sustainability. These robots operate autonomously, gracefully navigating corn fields with the aid of high-resolution imaging and real-time weed detection technologies. Their precision targeting ensures weeds are removed with surgical accuracy, reducing the need for herbicides, and promoting eco-friendly farming methods. Each robot, whether it's Hari Tech's autonomous navigation system or Carré's (Figure 6) customizable configurations, offers bespoke solutions to the unique challenges of weed management in corn cultivation.

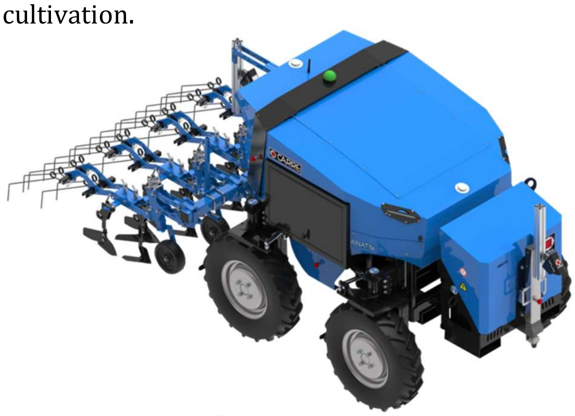

Figure 6 **Carré's ANATIS weeding robot**
(https://www.carre.fr/en/)

Through seamless integration of robotics and AI, these solutions streamline weed control, enhancing efficiency and productivity in corn fields. Farmers reap the benefits of reduced labor costs and increased yield potential as these robots efficiently combat weeds while preserving the health and vigor of corn crops. With their scalable designs and adaptable functionalities, these weeding robots herald a more sustainable future in corn cultivation, where weed-free fields and abundant harvests coexist harmoniously with environmental stewardship.

Robots and Drones for Crop Monitoring

In the realm of precision agriculture, Small Robot Co's Tom v4 (https://smallrobotco.com/) and XAG R150 (https://www.xa.com/en) stand as exemplars of innovation, reshaping the landscape of crop monitoring with their advanced capabilities. Tom v4 and XAG R150 (Figure 7) represent a convergence of cutting-edge technology and agricultural expertise, offering farmers unprecedented insights into their crops' health and productivity. Equipped with state-of-the-art sensors and intelligent algorithms, these autonomous robots navigate agricultural landscapes with ease, traversing fields while capturing high-resolution imagery and multispectral data. Their autonomous navigation systems, bolstered by GPS and obstacle avoidance technology, ensure efficient field coverage while avoiding obstacles in real-time. By analyzing this data, Tom v4 and XAG R150 provide farmers with actionable insights, from detecting pest infestations to monitoring crop growth trends, enabling informed decision-making and optimized resource usage. Furthermore, these robots are highly customizable, supporting a myriad of applications tailored to individual farm requirements, whether it's monitoring crop health, mapping soil moisture levels, or optimizing irrigation practices. Integration with precision farming systems further amplifies their utility, enabling seamless data synchronization with other agricultural machinery and management software, streamlining operations, and maximizing efficiency.

Figure 7 **XAG R150 monitoring robot**
(https://www.xa.com/en)

In an era defined by the imperative for sustainable agriculture and resource optimization, Small Robot Co's Tom v4 and XAG R150 emerge as indispensable allies for modern farmers, heralding a future of enhanced productivity and environmental stewardship in agriculture.

Potential Robot for Harvesting

In an endeavor to revolutionize agricultural machinery, LINTTAS Electric Company, a forward-thinking start-up headquartered in South Australia, is on the brink of unveiling a groundbreaking innovation: the world's inaugural fully electric combine harvester. This ambitious undertaking, underpinned by a commitment to sustainability, is poised to fundamentally alter the paradigm of grain harvesting, ushering in a new epoch characterized by enhanced efficiency, ecological consciousness, and technological prowess.

At its core, LINTTAS's electric combine epitomizes a convergence of cutting-edge technology and visionary design. Through the meticulous development of innovative grain separation processes, this pioneering harvester is meticulously crafted to deliver unparalleled speed and precision in corn harvesting. Its distinguishing features not only encompass heightened operational efficiency but also robust environmental credentials, boasting lower energy consumption and reduced operational costs that position it as a vanguard of sustainability within modern agriculture. However, LINTTAS acknowledges that genuine innovation transcends the machinery itself and extends to its seamless integration into agricultural workflows. Thus, we advocate for the exploration of strategic collaborations with industry stalwarts such as Trimble and John Deere. Through the incorporation of their state-of-the-art autosteer kits, there exists the potential to elevate the harvester's autonomy and efficiency to hitherto unprecedented levels, thereby paving the way for fully automated corn harvesting. Envision a scenario where autonomous harvesters traverse fields with consummate ease, guided by precision technology to optimize yield and minimize waste. This aspirational vision, while seemingly futuristic, is attainable through judicious partnerships and innovative breakthroughs. Such collaborations represent a significant milestone in agricultural technology, heralding a paradigm shift towards heightened productivity alongside a concomitant reduction in the ecological footprint of farming operations.

Figure 8 **Linttas electric combine**
(https://linttas.com/)

Moreover, the advent of fully automated corn harvesting portends profound implications for the sustainability of agriculture. By streamlining operations and diminishing reliance on manual labor, it not only enhances operational efficiency but also mitigates the environmental ramifications associated with traditional farming methods. Reduced fuel consumption, diminished soil compaction, and optimized resource utilization are among the myriad positive outcomes that stand to be realized through the embrace of autonomous harvesting. In essence, the manifold benefits of embracing autonomous technology in agriculture are both extensive and far-reaching. By leveraging the expertise of industry luminaries and pushing the boundaries of innovation, LINTTAS Electric Company endeavors to spearhead a veritable revolution in farming practices, wherein sustainability and efficiency stand as symbiotic pillars. Let us, therefore, collectively embark upon this transformative journey towards a greener, more prosperous future for agriculture and the planet at large.

CONCLUSIONS

In conclusion, this study presents a comprehensive examination of the global agricultural robotics market and its implications for fostering organic corn cultivation, particularly in the Western Plain of Romania. Through meticulous analysis of various companies and their multifunctional robotics offerings, ranging from soil preparation to crop monitoring and weed control, the study sheds light on the diverse technological landscape available for enhancing agricultural practices worldwide. Moreover, it emphasizes the significance of sustainability policies within the agricultural domain, with a focus on the European Union (EU), underscoring the importance of promoting organic farming standards and aligning with Sustainable Development Goals (SDGs) for a more inclusive and equitable agricultural sector. Insights gleaned from organizations such as CEMA, the European Parliament, FAO, and IFOAM highlight the pivotal role of intelligent agricultural machinery in advancing organic carbon farming methodologies and biodiversity-enhancing practices. By incorporating robotic technologies into different stages of corn cultivation, including data collection, soil preparation, seeding, phytosanitary treatments, weed elimination, and crop monitoring, farmers can leverage these innovations to revolutionize agricultural practices on a global scale.

Furthermore, the integration of renewable energy sources such as photovoltaic panels and biogas generators further reinforces the commitment to sustainability within the agricultural framework, aligning with the objectives of achieving self-sufficiency in energy and mitigating carbon emissions. This holistic approach not only addresses the immediate needs of agricultural productivity but also ensures long-term environmental resilience and social equity. In light of this, the innovative efforts of LINTTAS Electric Company in developing the world's first fully electric combine harvester present a compelling case for advancing sustainable agricultural practices. By integrating cutting-edge technology and visionary design, LINTTAS's electric combine epitomizes a convergence of efficiency, eco-consciousness, and technological prowess. Today, the sustainability of agriculture reflects the approach aimed at incorporating Industry 5.0 values (a human-centric approach for digital technologies, up-skilling and re-skilling European workers, particularly digital skills, modern, resource-efficient and sustainable industries and transition to a circular economy, a globally competitive and world-leading industry, speeding up investment in research and innovation) in what will be called Agriculture 5.0 (European Commission, 2022).

Overall, the study underscores the transformative potential of robotic technologies in advancing organic corn cultivation practices, enhancing efficiency, productivity, and sustainability in agricultural systems. By embracing these technological innovations and aligning with sustainable farming principles, farmers worldwide can navigate the complexities of modern agriculture while contributing to environmental stewardship, social inclusion, and food security goals for present and future generations.

Drones are starting to become a pillar of modern agriculture and are vastly used in the Western Plain of Romania, in turn making agriculture a more precise and stable endeavor. This year Bigger agricultural companies are starting to either adopt the usage of robots are starting to be interested in adapting them, it is also speculated that smaller companies and farms will be starting to adopt robots as early as next year since that's when robots will become more affordable and mainstream.

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