Sustainable Agriculture and Education for Long-Term Development

Simona Gavrilaș[1], Ioan Calinovici[2]

1. Faculty of Food Engineering, Tourism and Environmental Protection, Aurel Vlaicu University of Arad, simona.gavrilas@uav.ro, ORCID
2. Faculty of Food Engineering, Tourism and Environmental Protection, Aurel Vlaicu University of Arad, ioan.calinovici@uav.ro

DOI: 10.63467/alls15.art3

Abstract

Sustainable agriculture is becoming an essential pillar for sustainable development in the context of global challenges related to climate change, natural resource degradation, and population growth. This article explores the link between education and sustainable agriculture, with a special focus on the role of vocational training in adopting precision agriculture. Precision agriculture, based on modern technologies such as GPS, sensors, drones, and artificial intelligence, promises increased efficiency and reduced negative environmental impact. However, the success of its implementation depends significantly on the level of training of farmers and the capacity of educational institutions to respond to the demands of the modern agricultural market. The article analyzes the advantages and limitations of training in this field, proposes directions for improving educational curricula such as the local specific context, and provides recommendations for integrated public policies that support the transition to a

sustainable and digitalized agriculture. The conclusions emphasize the need for a synergistic approach between education, technology, and policies to ensure long-term sustainability.

Keywords: agroecological practices; agricultural policies; comparative analysis; green transition; vocational training

1. Introduction

In a global context marked by accelerated climate change, ecosystem degradation, and increasing pressure on natural resources, sustainable agriculture is becoming an essential condition for achieving sustainable development goals. However, this sector transformation cannot occur without a fundamental pillar: education (Durán Gabela et al., 2022). Access to quality vocational training, the development of green skills, and the promotion of lifelong learning are key elements in supporting a resilient agriculture, capable of responding to the economic, social, and ecological challenges of the 21st century.

The synergism between the two aspects could be of increased interest, especially when the system is active in rural areas. Education main role is to prepare well-trained specialists in the fields required mainly by the local economic sector. Another situation that may sustain the necessity of implementing new farming actions and training in the field relates to the family background. The possible heritage pass in the field to the youth may determine their career orientation and the intention to improve productivity through new strategies (Maini et al., 2021). In particular, the transition to modern practices, such as precision agriculture, requires a profound reform in agricultural education systems and the public policies that support them. The concept implementation requires investments in technology and human capital prepared to integrate digital knowledge, analyze complex data, and make informed decisions to protect the environment and increase efficiency. As a member of the European Union, Romania has the

opportunity and responsibility to build a durable agricultural system by combining new technologies with future-oriented education.

Implementing ”smart” agriculture instruments could contribute to improving natural resource management. A significant element in this area regards water managing. Use of the humidity detection level sensor and its maintenance according to crop needs is targeted. Another aspect that sustains the discussed technology’s implementation is improving the control of dispensed fertilizers and pesticides. Integrating automated elements could provide good operation practices of the three dimensions and determine a lower environmental impact of farming (Getahun et al., 2024).

The new perspective for the domain development also sustains an increased desire among the youth to be involved in the field. The context limits are determined by their interest in using computer-based instruments in their professional activities and the possibility of engaging in a green and attractive financial sector. Sanyaolu and Sadowski highlighted significant positive correlations between the tendency to use precision farming instruments and the environmental and economic aspects (Sanyaolu & Sadowski, 2024). The actions that sustain the results are linked to the possible reduction of production costs. This objective could be reached through two mechanisms. One refers to improving the efficiency of the stimulators used for crop grow by decreasing their quantity without affecting plant productivity and characteristics. The other one marks the possibility of accessing public grants.

Following up on intentional education in this field may decrease or eliminate some possible limitations. Basic knowledge in accessing financial support, field data evaluation, and ensuring their security (Mgendi, 2024), but also the ethical (Gamage et al., 2024), legislation and technical blankness (Jerhamre et al., 2022) aspects that may drift from this field are some considerations that might raise difficulties in adopting the future-specific instruments that are currently being developed, but which will forestall the domain in the future. All intentions are directed to

productivity and quality traceability to ensure the needs al the entire world population in expansion, but with controlled use of natural resources (Kumar et al., 2024).

This paper aims to analyze the interdependencies between education and sustainable agriculture, assess the role of vocational training in adopting ”smart” agriculture, and highlight strategic directions for the long-term development of this vital sector. The future of the agriculture sector integrates the precision agriculture instruments, and the way to use them in the field to optimize the domain outcomes.

2. Literature Review

The studies in the field underline that the interdependence between education and agricultural sustainability is increasingly highlighted. Vocational training could be considered a strategic factor in achieving durable development goals. Numerous studies have highlighted that farmers' education level is directly correlated with the degree of adoption of modern technologies, ecological practices, and efficient agricultural management methods. Kang et al. highlighted several possible benefits of implementing a smart farming learning manufactory in an educational institution. The advantages could be encountered at the students' practical and theoretical abilities acquisition level and for the economic actors. By benefiting from similar equipment to production units, students have acquired skills complementary to those acquired through on-the-job training courses. In this way, employers' costs for their practical training can be reduced (Wee et al., 2024).

European Council of Young Farmers (CEJA) makes a clear remark regarding three essential factors that contribute to the development of the future farmer. These relate to training for knowledge, education, and skills acquisition. Another important factor is the possibility of benefiting from innovative techniques, technology, and strategies. Neither of the two previous aspects could be performed without financial resources. Chen mentioned in his study the necessity of well-trained farmers for the future development of the rural areas. One important

element in their training is the skill to work with informational technologies (Chen, 2025). To accomplish such an objective, it is necessary to have an up-to-date curriculum, use active teaching methods, integrate the industry, and increase social awareness concerning vocational education for the field's development.

Being at the start of the implementation and a continuous development process, it is advisable to be flexible. For that, there is a need to adapt the teaching strategies to the specific realities of the field (Charles et al., 2020). Being involved in a seasonal activity, very much influenced by the weather conditions, the people interested in the field tend to prefer intensive, focused learning activities such as workshops and seminars (Oli et al., 2025). Forms of information, such as meetings, tutorials, or forums, could be adapted to online channels to ensure enlarged access to those interested. Chuang et al. underlined the necessity for lifelong learning in the field and the importance of disseminating the information related to the smart farming concept among farmers (Chuang et al., 2020). Some studies also mention a possible limiting factor for automated strategies besides the educational level and the enterprise size (Caffaro & Cavallo, 2019). Since the novel technologies initially have increased costs, small farmers are less likely to access them. Another important linked aspect concerns the possible expenses of training to get the needed knowledge to operate the technologies. There could be a reason why the entrepreneurs in the field have an increased yield of having more knowledge.

Although ten years ago, there were studies that underlined lower correlations between the farming practice adopted and the training level of the persons involved in the field (Meiguran & Basweti, 2016), there were recommendations for developing and raising awareness of literacy needs. Even if many of the employees in the farming sector had a low educational level, the current developments in the field tend to push the situation in a new direction: the need for specialized training. Some studies negatively correlate the willingness to implement new technologies in the field with the respondents' studies (Ewulo et al., 2025). The situation might be an alarm signal suggesting a possible gap between the current curriculum, the field's

socio-economic needs, and the necessity to form current skills and attitudes (Gemtou et al., 2024) and up-to-date visions in the education field (Yameogo et al., 2024). The intention to implement new development in the farming area could also be determined by the experience in the field or the specific local context (Erekalo et al., 2025). Considering these premises, educational policy implementation should be based on evaluating the concrete individual situations (Suebsombut et al., 2020).

3. Materials and Methods

The present investigation comprises an empirical evaluation of different EUROSTAT data regarding the evolution of the areas under green farming in Romania between 2006-2022. Comparative trends in vocational education and economic background for agriculture development in our country are also included.

4. Results and Discussions

4.1. Eco-friendly perspectives in farming areas

The interest in these data is justified by assessing the current status and trends in the field. The results are presented in **Figures 1** and **2**. The need to implement specific educational policies must also be sustained by the signals transmitted from the real socio-economic areas. **Figure 1** suggests increased interest in adopting environmentally friendly practices, especially after 2016. In the next six years, the percentage of the green regions' growth was over three times. That year was also the one declared as the International Year of Pulses by the Food and Agriculture Organization of the United Nations. Such initiatives tend to stimulate the various crop production sectors to ensure healthy natural nourishment sources and sustain the produce from a certain yield area.

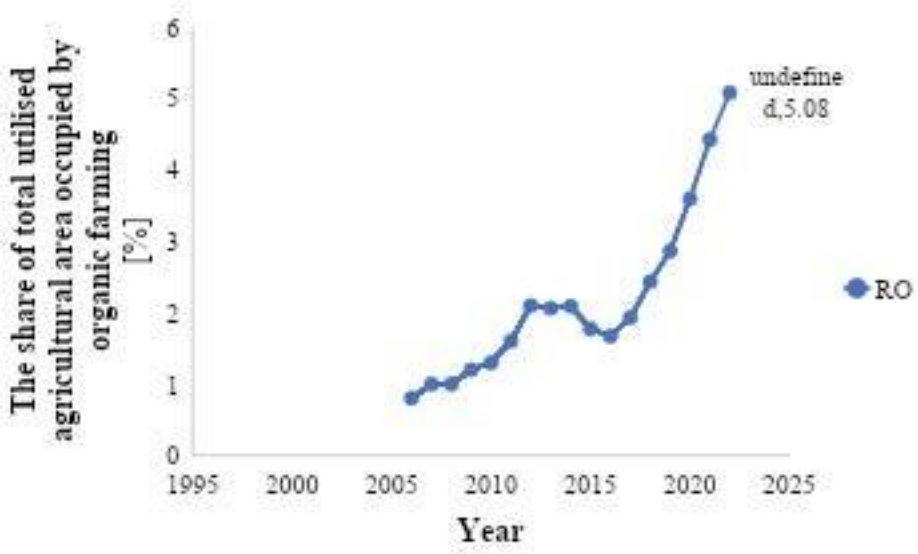

Figure 1. Organic farming share in Romania

Source: EUROSTAT

Another aspect targeted referred to the possibilities offered by the farming domains to the youth. There, the study concentrated on determining the percentages of used areas to assess if there are possibilities to begin an entrepreneurial activity.

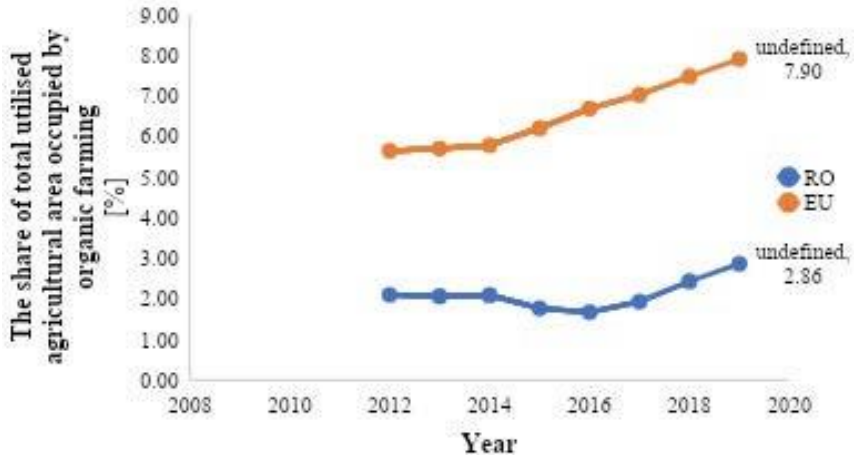

Figure 2. Organic farming share comparative evolution in Romania and the European Union

Source: EUROSTAT

Figure 2 shows the transition to organic farming in Romania and the European Union. It reveals the trend of the indicator that measures the share of total utilised agricultural area (UAA) occupied by organic farming. This class includes the existing organically-farmed regions and areas in the conversion process. As observed, the percentage of land used in Romania's based on this concept is almost three times lower than that reported at the EU level. This situation may be considered an opportunity for study in the field with a sustainable perspective on professional further activating.

4.2. Education in the vocational field and a specific economic setting

Since the enrolment in farming education could be determined by personal initial affinities, family background, and skills were also analyzed the data regarding the children who follow vocational programs. **Figure 3** shows the situation reported in 2022.

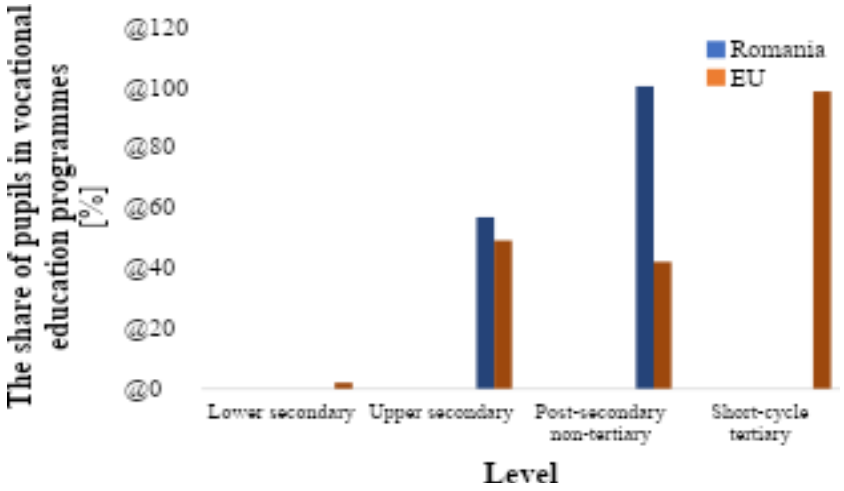

Figure 3. Percentage of students pursuing vocational education by level of training

Source: EUROSTAT

Compared to the situation on the European level in Romania, there is a higher interest in the post-secondary non-tertiary level of vocational education. There is no data regarding the lower secondary or short-cycle stages.

There is a need to increase the awareness of the necessity to improve specific skills in automated, machine learning concepts for future farmers. Process optimization will determine a less environmental impact of the activity and also economic efficiency. A forthcoming responsible agriculture has to be based on training models for farming education that require responsibility and knowledge for improved results (Farid et al., 2020). The learning process refers to the current persons involved in the domain and the youth, who could consider such a domain attractive. Active learning is also necessary, determined by the unpredictability of nature, characterized by multiple variables. These could be difficult to manage without integrating the current element of technological progress (Ritz et al., 2019).

To increase the youth's aspiration to be involved in the agriculture domain and be willing to study it, a key element could be represented by the performance registered in the sector. Using

the net entrepreneurial income of agriculture (Indicator C), **Figure 4** was obtained. A comparative chart of the data reported for Romania and the European level for ten years was made.

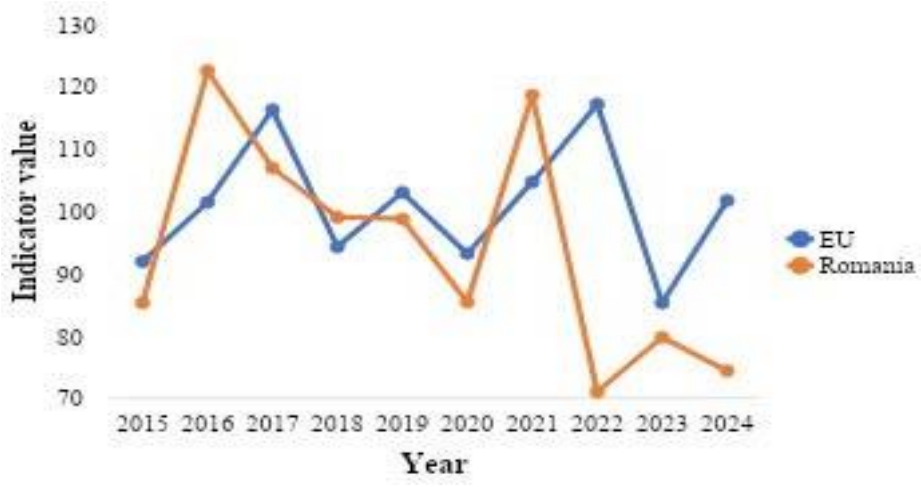

Figure 4. The annual *Indicator C* variation

Source: EUROSTAT

From **Figure 4** can be observed that the tendencies in Romania mostly follow the ones encountered at the European Union level. The trend differences appear between 2023 and 2024, where the directions are opposed, to the disservice of our county. The sector revigoration could happen since it closely depends on climate conditions and the region's market evolution.

Low educational participation could be correlated with low adoption of precision agriculture and organic practices. The transition to sustainable agriculture remains limited without a coherent national strategy for continuously training farmers.

5. Conclusions, Recommendations, and Future Developments

The results of the theoretical and empirical analysis highlight a clear relationship between the level of education and the ability of farmers to adopt sustainable practices, especially in the context of precision agriculture and the ecological transition. In the case of Romania, the underdevelopment of the vocational training infrastructure and the low participation in continuing education constitute major obstacles to the modernization of agriculture. To improve the situation, different initiatives may contribute. Some may refer to program reviewing, educators' coaching platforms, cooperation between schools, other educational institutions, farmers, national and local administrative institutions, and equipment developers (Nugroho et al., 2024).

It is essential to update the curricula in agricultural high schools and universities to integrate topics related to sustainability, digitalization, precision agriculture, and green skills. The programs should include theoretical and applied practice, collaborating with model farms and innovation centers.

Through the Ministry of Agriculture and local structures, the government should support continuous training through free or subsidized courses in collaboration with agricultural chambers, NGOs, and universities. A functional reactivation of the farming advisory system is necessary. Making access to certain forms of subsidies (e.g., investments in precision or organic agriculture) conditional on participation in training courses can be an effective method for accelerating the development of relevant skills. Creating a national digital platform for agricultural education, with free and interactive resources, can facilitate access to training for farmers in isolated or disadvantaged areas.

The transition to sustainable agriculture in Romania is impossible without a coherent and long-term investment in education. Both initial and continuous training are essential in equipping farmers with the necessary skills to adopt modern, efficient, and environmentally responsible practices. Precision agriculture, a symbol of innovation in the agricultural sector, cannot be

implemented effectively without well-trained human capital. The data support the idea that there is a correlation between the level of education and farming performance regarding productivity and sustainability to overcome the differences between the expectations and the reality (Simões & Brito do Rio, 2020).

Thus, to achieve the sustainable development goals, Romania must create an educational ecosystem adapted to the needs of future agriculture, in which training, innovation, and knowledge transfer become central pillars of national agricultural policies.

Acknowledgment:

The search was developed as an activity in the ERASMUS+ Project, **2023-1-DE01-KA220-HED-000166720-***The Future of Precision Agriculture-Machine Learning for Autonomous Decision Mechanism-"SMART Farming"*.

References

Caffaro, F., & Cavallo, E. (2019). The Effects of Individual Variables, Farming System Characteristics and Perceived Barriers on Actual Use of Smart Farming Technologies: Evidence from the Piedmont Region, Northwestern Italy. *9*(5), 111, https://www.mdpi.com/2077-0472/9/5/111.

Charles, A., Gay, C., Suebsombut, P., & Prasain, K. (2020). An adaptive learning approach to train smart farmers in Thailand, Bhutan and Nepal. ICMET, https://hal.science/hal-03960152/document.

Chen, Z. (2025). Implementation Pathways for Vocational Education in Supporting the Cultivation of High-Quality Farmers. *Journal of Theory Practice in Education Innovation*, *2*(1), pp. 15-21, https://woodyinternational.com/index.php/jtpei/article/view/141/115.

Chuang, J.-H., Wang, J.-H., & Liou, Y.-C. (2020). Farmers' Knowledge, Attitude, and Adoption of Smart Agriculture Technology in Taiwan. *International Journal of Environmental Research and Public Health*, *17*(19), 7236, https://doi.org/10.3390/ijerph17197236.

Durán Gabela, C., Trejos, B., Lamiño Jaramillo, P., & Boren-Alpízar, A. (2022). Sustainable Agriculture: Relationship between Knowledge and Attitude among University Students. *Sustainability*, *14*(23), 15523, https://doi.org/10.3390/su142315523.

Erekalo, K. T., Gemtou, M., Kornelis, M., Pedersen, S. M., Christensen, T., & Denver, S. (2025). Understanding the behavioral factors influencing farmers' future adoption of climate-smart agriculture: A multi-group analysis. *Journal of Cleaner Production*, *510*, 145632, https://doi.org/10.1016/j.jclepro.2025.145632.

Ewulo, T. A., Akinseye, F. M., Teme, N., Agele, S. O., Yessoufou, N., & Kumar, S. (2025). Factors driving Climate-Smart Agriculture adoption: a study of smallholder farmers in Koumpentum, Senegal. *Frontiers in Agronomy*, *7*, 1552720, https://doi.org/10.3389/fagro.2025.1552720.

Farid, D. M., Sekhari, A., & Ouzrout, Y. (2020). Cluster-Based Knowledge Transfer Approach for Smart Farming. 12th annual International Conference on Education and New Learning Technologies (IATED EDULEARN 20), https://hal.science/hal-03082321/document.

Gamage, A., Gangahagedara, R., Subasinghe, S., Gamage, J., Guruge, C., Senaratne, S., . . . Merah, O. (2024). Advancing sustainability: The impact of emerging technologies in agriculture. *Current Plant Biology*, *40*, 100420, https://doi.org/10.1016/j.cpb.2024.100420.

Gemtou, M., Kakkavou, K., Anastasiou, E., Fountas, S., Pedersen, S. M., Isakhanyan, G., . . . Pazos-Vidal, S. (2024). Farmers' Transition to Climate-Smart Agriculture: A Systematic Review of the Decision-Making Factors Affecting Adoption. *Sustainability*, *16*(7), 2828, https://doi.org/10.3390/su16072828.

Getahun, S., Kefale, H., & Gelaye, Y. (2024). Application of precision agriculture technologies for sustainable crop production and environmental sustainability: A systematic review. *The Scientific World Journal*, *2024*(1), 2126734, https://doi.org/10.1155/2024/2126734.

Jerhamre, E., Carlberg, C. J. C., & van Zoest, V. (2022). Exploring the susceptibility of smart farming: Identified opportunities and challenges. *Smart Agricultural Technology*, *2*, 100026, https://doi.org/10.1016/j.atech.2021.100026.

Kumar, S., Wani, A. W., Kaushik, R., Kaur, H., Djajadi, D., Khamidah, A., . . . Wani, A. K. (2024). Navigating the landscape of precision horticulture: Sustainable agriculture in the digital Age. *Scientia Horticulturae*, *338*, 113688, https://doi.org/10.1016/j.scienta.2024.113688.

Maini, E., De Rosa, M., & Vecchio, Y. (2021). The Role of Education in the Transition towards Sustainable Agriculture: A Family Farm Learning Perspective. *Sustainability*, *13*(14), 8099, https://doi.org/10.3390/su13148099.

Meiguran, M., & Basweti, E. (2016). Influence of Farmer Level of Education on the Practice of Improved Agricultural Technologies: A Case of Nyamusi Division, Kenya. *International Journal of Recent Research in Interdisciplinary Sciences*, *3*(3), pp. 19-27, https://www.paperpublications.org/upload/book/Infleunce%20of%20Farmer%20Level-811.pdf.

Mgendi, G. (2024). Unlocking the potential of precision agriculture for sustainable farming. *Discover Agriculture*, *2*(1), 87, https://doi.org/10.1007/s44279-024-00078-3.

Nugroho, A. W., Suwanda, T., Yudha, F. A. K., Kurniawan, A., & Lina, H. N. (2024). Utilization of Smart Farming Learning Media based on the Internet of Things to Improve the Competence of Vocational Teachers. Proceeding International Conference of Community Service, https://doi.org/10.18196/iccs.v2i1.329.

Oli, D., Gyawali, B., Acharya, S., & Oshikoya, S. (2025). Factors influencing learning attitude of farmers regarding adoption of farming technologies in farms of Kentucky, USA. *Smart Agricultural Technology*, *10*, 100801, https://doi.org/10.1016/j.atech.2025.100801.

Ritz, S., Rizzo, D., Dantan, J., FOURATI-JAMOUSSI, F., Dubois, M., & Combaud, A. J. F., Villepinte, France. (2019). Training in agricultural technologies: a new prerequisite for smart farming, . *3rd Rendez-Vous Techniques AXEMA*, https://hal.science/hal-03153999/document.

Sanyaolu, M., & Sadowski, A. (2024). The Role of Precision Agriculture Technologies in Enhancing Sustainable Agriculture. *Sustainability*, *16*(15), 6668, https://doi.org/10.3390/su16156668.

Simões, F., & Brito do Rio, N. (2020). How to increase rural NEETs professional involvement in agriculture? The roles of youth representations and vocational training packages improvement. *Journal of Rural Studies*, *75*, pp. 9-19, https://doi.org/10.1016/j.jrurstud.2020.02.007.

Suebsombut, P., Chernbumroong, S., Sureephong, P., Jaroenwanit, P., Phuensane, P., & Sekhari, A. (2020). Comparison of smart agriculture literacy of farmers in Thailand. 2020 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT & NCON), https://hal.science/hal-04173412/document.

Wee, Y., Kang, Y., & Kim, W. (2024). Smart Farming for Sustainable Agriculture: A Case Study through Korean Public TVET. *Journal of Technical Education Training*, *16*(2), 195-208, https://doi.org/10.30880/jtet.2024.16.02.017.

Yameogo, V., Zossou, R. C., Daum, T., Scheiterle, L., Adegbola, Y. P., Daudu, C., . . . Fatunbi, O. (2024). Moving from Productivity to Sustainability in Agricultural Education? Perspectives from Students and Teachers in four African Countries. *Hohenheim Working Papers on Social and Institutional Change in Agricultural Development 023-2024. University of Hohenheim*, https://490c.uni-hohenheim.de/fileadmin/einrichtungen/490c/Publications/ATVET_Working_paper_May_2024_WP_023-2024.pdf.