Mechanization and Engineering Innovations for Sustainable Horticultural Systems

Applications in Precision Agriculture, Robotics, and Post-Harvest Technologies

Kalluri Praveen
S. Reddy Veera Nagaveni

DeepScience

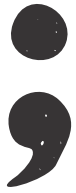
Mechanization and Engineering Innovations for Sustainable Horticultural Systems: Applications in Precision Agriculture, Robotics, and Post-Harvest Technologies

Kalluri Praveen

CAE, JNKVV, Jabalpur, (Madya Pradesh), 482004

S. Reddy Veera Nagaveni

CoA, CAE, JNKVV, Jabalpur, (Madya Pradesh), 482004



DeepScience

Published, marketed, and distributed by:

Deep Science Publishing, 2025
USA | UK | India | Turkey
Reg. No. MH-33-0523625
www.deepscienceresearch.com
editor@deepscienceresearch.com
WhatsApp: +91 7977171947

ISBN: 978-93-7185-313-2

E-ISBN: 978-93-7185-341-5

https://doi.org/10.70593/978-93-7185-341-5

Citation: Praveen, K. & Nagaveni, S.R.V. (2025). *Mechanization and Engineering Innovations for Sustainable Horticultural Systems: Applications in Precision Agriculture, Robotics, and Post-Harvest Technologies*. Deep Science Publishing. https://doi.org/10.70593/978-93-7185-341-5

Preface

The increasing need for more quantity and quality of horticultural produce necessitates the application of science, technology, and engineering for their production. Mechanization and Engineering Interventions in Horticulture seeks to introduce and familiarize students, professionals, and other interested people with agricultural engineering as a modern and sustainable technique for horticulture.

The book has ten chapters, beginning with introducing the significance of horticultural engineering in horticulture. It proceeds to discuss areas such as machinery and irrigation systems, soil and tillage management, greenhouse technology, post-harvest handling, mechanization of harvesting, robotics, and automation. The last chapter is dedicated to sustainable practices and innovation in the future.

Each chapter presents crisp concepts, real-world applications, and latest developments. The book is a culmination of lifelong experience and research, and it is intended to be a useful handbook for horticultural engineering students, practitioners, and innovators.

Dr. Kalluri Praveen

S. Reddy Veera Nagaveni

Table of Contents

Deep Science Publishing, 2025
https://doi.org/10.70593/978-93-7185-341-5

DeepScience
Open Access Books

Chapter 1: Introduction to Agricultural Engineering in Horticulture

1 Definition and Scope of Agricultural Engineering in Horticulture

Agricultural engineering in horticulture is the application of engineering knowledge and technologies towards increasing productivity, efficiency, sustainability, and profitability of horticultural product production systems [1]. It is concerned with designing, developing, and utilizing tools, equipment, structures, and systems enabling the cultivation, harvesting, processing, and storage of fruits, vegetables, flower crops, ornamental plants, spices, and medicinal crops [2].

The importance of agricultural engineering in horticulture covers a vast field and is progressing dynamically with regard to different phases of work–land preparation, sowing and planting, irrigation control, fertigation, protection of plants, climatic control, harvesting, post-harvest operations, and value addition [3], where technical persons and engineers are engaged in tailoring and streamlining themselves to extend the scientific and technical operations to suit the specific requirements of horticultural crops, which are more sensitive and need specified treatments than crops grown in fields.

Scope encompasses protected cultivation (greenhouses, polyhouses, and shade nets), precision agriculture, sensor-based monitoring, and decision-making based on data. Not only do these technologies function to augmenting quality and quantity, but also to reduce the usage of resources, make the processes more environmentally friendly, and combat manpower shortages [4].

1.2 Importance of Engineering Technologies in Improving Horticultural Practices

Technology does have a very important role in changing traditional horticultural practices into effective, modern, and sustainable systems. Horticulture does likely enjoy the greatest advantage from mechanization and automation, which reduces the labor-intensive nature of horticulture, thereby resulting in increased productivity and reduced production costs [5]

References

[1] Indurthi S, Sarma I, Vinod DV. Horticultural innovations elevating crop yields and agricultural sustainability for a flourishing future. Plant Cell Biotechnol Mol Biol. 2024;25(1-2):22-44.

[2] Satisha J. Horticultural crops. In: Trajectory of 75 years of Indian agriculture after independence. Singapore: Springer Nature Singapore; 2023. p. 265-293.

[3] Jha SN, Singh K, Mehta C, Kotwaliwale N, Saxena S, Shakyawar D, et al. Achievements in agricultural engineering in independent India. In: Indian agriculture after independence. 1st ed. New Delhi: Indian Council Agricultural Research; 2022. p. 282-310.

[4] Suresh R, Nirala S. Precision farming techniques for protected cultivation. New Delhi: PHI Learning Pvt. Ltd.; 2024.

[5] Yadav ES, Chandravanshi AK, Shukla EP. Mechanized horticulture: transformative advances and sustainable practices. In: Recent advances and innovations in agricultural machinery. 2024.

[6] Gammanpila HW, Sashika MN, Priyadarshani SVGN. Advancing horticultural crop loss reduction through robotic and AI technologies: innovations, applications, and practical implications. Adv Agric. 2024;2024(1):2472111.

[7] Pathania J, Verma P, Bodh S, Da S. Role of robotics and artificial intelligence in horticulture for sustainable resource development: a review. Environ Eng Manag J. 2025;24(1).

[8] Yadav ES, Chandravanshi AK, Shukla EP. Mechanized horticulture: transformative advances and sustainable practices. In: Recent advances and innovations in agricultural machinery. 2024.

[9] Nage SM, Mathur SM, Meena SS, Singh V, Joshi S. Semi-automatic vegetable transplanters: a review. J Plant Sci Res. 2023;39(1).

[10] Kumar KY, Reddy VN, Moses SC, Aalam RN, Singh S. Design, development and evaluation of manual vegetable transplanter. Int J Curr Microbiol App Sci. 2021;10(1):497-508.

[11] Nage SM, Mathur SM, Meena SS. Vegetable transplanters for India: a review. Agric Sci Digest. 2023;43(2):129-34.

[12] Ningthoujam B, Singh V, Nilatkar DK. Design and development of wooden plate metering device for onion bulb planter. Int J Appl Sci Eng. 2016;4(2):111-23.

[13] Khadatkar A, Mathur SM, Dubey K, BhusanaBabu V. Development of embedded automatic transplanting system in seedling transplanters for precision agriculture. Artif Intell Agric. 2021;5:175-84.

[14] Kosariya YK. Recent cultivation practices in some horticultural crops. In: Recent advances and innovations in agricultural machinery. Ropan; 2024. p. 69-80.

[15] Ramya SK, Kumar SS. Significance of micro-irrigation for feasible and sustainable agriculture: a review. Multidiscip Rev. 2025;8(4):2025094.

[16] Moreno R, Torregrosa A, Moltó E, Chueca P. Effect of harvesting with a trunk shaker and an abscission chemical on fruit detachment and defoliation of citrus grown under Mediterranean conditions. Span J Agric Res. 2015;13(1).

[17] Kumawat L, Raheman H. Mechanization in onion harvesting and its performance: a review and a conceptual design of onion harvester from Indian perspective. J Inst Eng India Ser A. 2022;103(1):295-304.
[18] Afsah-Hejri L, Homayouni T, Toudeshki A, Ehsani R, Ferguson L, Castro-García S. Mechanical harvesting of selected temperate and tropical fruit and nut trees. Hortic Rev (Am Soc Hortic Sci). 2022;49:171-242.
[19] Jin Y, Wang J, Chen J, Song Z, Zhang R, Zhou R. Design and experiment for flexible clamping and conveying device for green leafy vegetable orderly harvester. Agriculture. 2024;14(6):967.
[20] Olowojola CO, Faleye T, Agbetoye LAS. Development and performance evaluation of a leafy vegetable harvester. 2011.
[21] Navone A, Martini M, Chiaberge M. Autonomous robotic pruning in orchards and vineyards: a review. arXiv [Preprint]. 2025 May 12. arXiv:2505.07318.
[22] Settlage K. Vertical gardening using trellises, stakes and cages. Virginia Cooperative Extension Publications; 2014.
[23] Kumar SP, Roul AK, Nandede BM, Jyoti B, Chethan CR. Development of small tractor operated boom sprayer for effective control of weeds in maize. 2021.
[24] Bound SA. Spray technology in perennial tree crops. In: Dris R, Niskanen R, editors. Production practices and quality assessment of food crops. Vol 1: Preharvest practice. Dordrecht: Springer Netherlands; 2004. p. 83-104.
[25] Fox RD, Derksen RC, Zhu H, Brazee RD, Svensson SA. A history of air-blast sprayer development and future prospects. Trans ASABE. 2008;51(2):405-10.
[26] Bai Q, Luo H, Fu X, Zhang X, Li G. Design and experiment of lightweight dual-mode automatic variable-rate fertilization device and control system. Agriculture. 2023;13(6):1138.
[27] Chandra U, Shukla G, Maheshwari H, Tripathi S. An advanced approach to agriculture using IoT and WSN. Int Res J Commerce Arts Sci. 2024;15(5):348-55.
[28] Li Q, Yang Y, Jiang P. Remote monitoring and maintenance for equipment and production lines on industrial internet: a literature review. Machines. 2022;11(1):12.
[29] Kumar D, Choudhary V, Kumar N, Jyoti B, Mandal S, Jeet P, et al. Robots for harvesting of horticultural crop: a review: harvesting fruits by robots. J AgriSearch. 2024;11(3):152-64.
[30] Steward B, Gai J, Tang L. The use of agricultural robots in weed management and control. In: Pedersen SM, Lindblom J, editors. Robotics and automation for improving agriculture. Cambridge: Burleigh Dodds Science Publishing; 2019. p. 161-86.
[31] Cyriac R, Thomas J. Smart farming with cloud supported data management enabling real-time monitoring and prediction for better yield. In: Jayasuriya S, Herath H, editors. Intelligent robots and drones for precision agriculture. Cham: Springer Nature Switzerland; 2024. p. 283-306.
[32] Das GP, Gould I, Zarafshan P, Heselden J, Badiee A, Wright I, Pearson S. Applications of robotic and solar energy in precision agriculture and smart farming. In: Eltawil MA, editor. Solar energy advancements in agriculture and food production systems. Cambridge: Academic Press; 2022. p. 351-90.

[33] Bhavsar D, Limbasia B, Mori Y, Aglodiya MI, Shah M. A comprehensive and systematic study in smart drip and sprinkler irrigation systems. Smart Agric Technol. 2023;5:100303.
[34] Shareef TME, Ma Z, Zhao B. Essentials of drip irrigation system for saving water and nutrients to plant roots: as a guide for growers. J Water Resour Prot. 2019;11(9):1129-45.
[35] Olamide FO, Olalekan BA, Tobi SU, Adeyemi MA, Julius JO, Oluwaseyi FK. Fundamentals of irrigation methods and their impact on crop production. In: Irrigation and drainage—recent advances. London: IntechOpen; 2022.
[36] Goyal MR, Sivanappan RK. Engineering practices for agricultural production and water conservation: an interdisciplinary approach. Vol. 3. Boca Raton: CRC Press; 2017.
[37] Tenreiro TR, García-Vila M, Gómez JA, Jimenez-Berni JA, Fereres E. Water modelling approaches and opportunities to simulate spatial water variations at crop field level. Agric Water Manag. 2020;240:106254.
[38] Lakhiar IA, Yan H, Zhang C, Wang G, He B, Hao B, et al. A review of precision irrigation water-saving technology under changing climate for enhancing water use efficiency, crop yield, and environmental footprints. Agriculture. 2024;14(7):1141.
[39] Bwambale E, Naangmenyele Z, Iradukunda P, Agboka KM, Houessou-Dossou EA, Akansake DA, et al. Towards precision irrigation management: a review of GIS, remote sensing and emerging technologies. Cogent Eng. 2022;9(1):2100573.
[40] Alkhayer I. Design and performance analysis of irrigation networks operating on demand in developing countries. In: Proceedings—Book of Abstracts. 2015. p. 50.
[41] Obaideen K, Yousef BA, AlMallahi MN, Tan YC, Mahmoud M, Jaber H, et al. An overview of smart irrigation systems using IoT. Energy Nexus. 2022; 7:100124.
[42] Cardenas-Lailhacar B, Dukes MD, Miller GL. Sensor-based automation of irrigation on bermudagrass during wet weather conditions. J Irrig Drain Eng. 2008;134(2):120-8.
[43] Angon PB, Anjum N, Akter MM, KC S, Suma RP, Jannat S. An overview of the impact of tillage and cropping systems on soil health in agricultural practices. Adv Agric. 2023;2023(1):8861216.
[44] Monger C, Michéli E, Aburto F, Itkin D. Soil classification as a tool for contributing to sustainability at the landscape scale and forecasting impacts of management practices in agriculture and forestry. Soil Tillage Res. 2024;244:106216.
[45] Nazemosadat SMR, Ghanbarian D, Naderi-Boldaji M, Nematollahi MA. Structural analysis of a mounted moldboard plow using the finite element simulation method. Span J Agric Res. 2022;20(2):e0204.
[46] Alla B, Verma BM. Design and analysis of a rotavator. Int Res J Eng Technol. 2021;8(12):730-42.
[47] Böğrekci İ, Demircioğlu P, Ozer G. Design and analysis of cost-effective compact disc harrow. Int J 3D Print Technol Digit Ind. 2022;6(2):228-35.
[48] Chen W, Hu L, Wang G, Yuan J, Bao G, Shen H, et al. Design of 4UM-120D electric leafy vegetable harvester cutter height off the ground automatic control system based on incremental PID. Agriculture. 2023;13(4):905.
[49] Singh NK, Dogra B, Manes GS, Parihar DS, Salem A, Elbeltagi A. Effect of the spading machine on various soil parameters at different tillage depths. Sustainability. 2024;16(11):4334.

[50] Lal R, Eckert DJ, Fausey NR, Edwards WM. Conservation tillage in sustainable agriculture. In: Sustainable agricultural systems. Boca Raton: CRC Press; 2020. p. 203-25.
[51] Huss CP, Holmes KD, Blubaugh CK. Benefits and risks of intercropping for crop resilience and pest management. J Econ Entomol. 2022;115(5):1350-62.
[52] Wang Z, Williams M, Jacobsen K, Coolong T. Impact of tillage and irrigation management on bell pepper (Capsicum annuum L.) grown in organic and conventional production systems. HortScience. 2015;50(11):1694-701.
[53] Futa B, Gmitrowicz-Iwan J, Skersienė A, Šlepetienė A, Parašotas I. Innovative soil management strategies for sustainable agriculture. Sustainability. 2024;16(21):9481.
[54] Fan Y, Wang X, Funk T, Rashid I, Herman B, Bompoti N, et al. A critical review for real-time continuous soil monitoring: advantages, challenges, and perspectives. Environ Sci Technol. 2022;56(19):13546-64.
[55] Petrone A, Preti F. Soil bioengineering for risk mitigation and environmental restoration in a humid tropical area. Hydrol Earth Syst Sci. 2010;14(2):239-50.
[56] Sekhon SS, Kumar V, Patel A, Parmar BS. Technological advances in smart and sustainable agriculture: the role of internet of things, artificial intelligence, big data analysis, machine learning & deep learning. In: Food and industry 5.0: transforming the food system for a sustainable future. 2025. p. 61-71.
[57] Meusburger HS, Paterson C, Schubert D, Zabel P. Greenhouses and their humanizing synergies. Acta Astronaut. 2014;96:138-50.
[58] Zhang B, Liu Y, Zhang H, Shen C, Fu W. Design and evaluation of a shaping and pruning machine for dwarf and densely planted jujube trees. Appl Sci. 2022;12(5):2699.
[59] Maraveas C, Karavas CS, Loukatos D, Bartzanas T, Arvanitis KG, Symeonaki E. Agricultural greenhouses: resource management technologies and perspectives for zero greenhouse gas emissions. Agriculture. 2023;13(7):1464.
[60] Burchi G, Chessa S, Gambineri F, Kocian A, Massa D, Milazzo P, et al. Information technology controlled greenhouse: a system architecture. In: 2018 IoT Vertical and Topical Summit on Agriculture-Tuscany (IOT Tuscany); 2018 May; Tuscany, Italy. IEEE; 2018. p. 1-6.
[61] Hemming S. Use of natural and artificial light in horticulture—interaction of plant and technology. In: VI International Symposium on Light in Horticulture; 2009 Nov; Wageningen, Netherlands. Acta Hortic. 2009;907:25-35.
[62] Tangarife HI, Díaz AE. Robotic applications in the automation of agricultural production under greenhouse: a review. In: 2017 IEEE 3rd Colombian Conference on Automatic Control (CCAC); 2017 Oct; Cartagena, Colombia. IEEE; 2017. p. 1-6.
[63] Anand R, Malkani P, Rathod SK, Jha DK, Swain SS, Kumar S, et al. Robotic harvesters for fruits and vegetables. In: Advances in Agriculture Sciences. Vol. 43. Delhi: AkiNik Publications; 2023. p. 51-62.
[64] Khadatkar A, Pandirwar AP, Paradkar VJSR. Design, development and application of a compact robotic transplanter with automatic seedling picking mechanism for plug-type seedlings. Sci Rep. 2023;13(1):1883.
[65] Tran DT, Le HS, Huh JH. Building an automatic irrigation fertilization system for smart farm in greenhouse. IEEE Trans Consum Electron. 2023;69(4):[epub ahead of print].

[66] Jin X, Li M, Li D, Ji J, Pang J, Wang J, et al. Development of automatic conveying system for vegetable seedlings. EURASIP J Wirel Commun Netw. 2018;2018(1):178.
[67] Bisht A, Singh SP. Postharvest losses and management of horticultural produce: a review. J Sci Res Rep. 2024;30:305-20.
[68] Kader AA, Rolle RS. The role of post-harvest management in assuring the quality and safety of horticultural produce. Rome: Food and Agriculture Organization; 2004. Report No.: 152.
[69] Das B, Hoque A, Roy S, Kumar K, Laskar AA, Mazumder AS. Post-harvest technologies and automation: AI-driven innovations in food processing and supply chains. 2025.
[70] Kitinoja L, Kader AA. Small-scale postharvest handling practices: a manual for horticultural crops. 4th ed. Davis (CA): University of California, Postharvest Technology Research and Information Center; 2002.
[71] Sudheer KP, Indira V. Post harvest technology of horticultural crops. New Delhi: New India Publishing; 2007. Vol. 7.
[72] Bodbodak S, Moshfeghifar M. Advances in controlled atmosphere storage of fruits and vegetables. In: Eco-friendly technology for postharvest produce quality. London: Academic Press; 2016. p. 39-76.
[73] Kou X, Feng Y, Yuan S, Zhao X, Wu C, Wang C, et al. Different regulatory mechanisms of plant hormones in the ripening of climacteric and non-climacteric fruits: a review. Plant Mol Biol. 2021;105(6):1-21.
[74] Mahmood MH, Sultan M, Miyazaki T. Significance of temperature and humidity control for agricultural products storage: overview of conventional and advanced options. Int J Food Eng. 2019;15(10):[epub ahead of print].
[75] Paull R. Effect of temperature and relative humidity on fresh commodity quality. Postharvest Biol Technol. 1999;15(3):263-77.
[76] Mohammed M, Riad K, Alqahtani N. Design of a smart IoT-based control system for remotely managing cold storage facilities. Sensors. 2022;22(13):4680.
[77] Al-Dairi M, Pathare PB, Al-Yahyai R, Opara UL. Mechanical damage of fresh produce in postharvest transportation: current status and future prospects. Trends Food Sci Technol. 2022;124:195-207.
[78] Mangaraj S, Goswami TK. Modified atmosphere packaging of fruits and vegetables for extending shelf-life: a review. Fresh Prod. 2009;3(1):1-31.
[79] Hewett EW. An overview of preharvest factors influencing postharvest quality of horticultural products. Int J Postharvest Technol Innov. 2006;1(1):4-15.
[80] Eskin M, Robinson DS. Mechanical and temperature effects on shelf-life stability of fruits and vegetables. In: Eskin M, Robinson DS, editors. Food shelf-life stability. Boca Raton (FL): CRC Press; 2000. p. 49-98.
[81] Khandetod YP. Mechanization in horticulture crops: present status and future scope. Adv Agric Res Technol J. 2019;3(1):92-103.
[82] Sims B, Heney J. Promoting smallholder adoption of conservation agriculture through mechanization services. Agriculture. 2017;7(8):64.
[83] Bhatia BS. Adoption of farm mechanization in a developing economy. New Delhi: Daya Books; 1999.

[84] Pu Y, Wang S, Yang F, Ehsani R, Zhao L, Li C, et al. Recent progress and future prospects for mechanized harvesting of fruit crops with shaking systems. Int J Agric Biol Eng. 2023;16(1):1-13.
[85] Zhang J, Kang N, Qu Q, Zhou L, Zhang H. Automatic fruit picking technology: a comprehensive review of research advances. Artif Intell Rev. 2024;57(3):54.
[86] Gong Z, Song Q, Yang Y. Development and evaluation of mechanical harvesting of root crops and its performance optimization. In: 2023 7th International Conference on Electrical, Mechanical and Computer Engineering (ICEMCE); 2023 Oct; IEEE. p. 782-8.
[87] Brondino L, Borra D, Giuggioli NR, Massaglia S. Mechanized blueberry harvesting: preliminary results in the Italian context. Agriculture. 2021;11(12):1197.
[88] Sengaphone P, De Leon JM, Concepcion R, Bandala AA, Augusto GL, Naguib R, et al. End-effectors of the robotic arms for tomato harvesting: a comprehensive review. J Comput Appl Res Mech Eng. 2024;14(1):1-18.
[89] Aswathi K, Tiwari VK, Vadher AL. Enhancing efficiency and reducing costs through self-propelled leafy crop harvester for coriander, fenugreek, and Indian spinach. 2023.
[90] Hutsol T, Kutyrev A, Kiktev N, Biliuk M. Robotic technologies in horticulture: analysis and implementation prospects. Agric Eng. 2023;27.
[91] Singh G, Bhagat N, Thakur S. Automated production management in horticulture: an Industry 4.0 perspective. In: Blockchain-enabled Internet of Things applications in healthcare: current practices and future directions. Sharjah: Bentham Science Publishers; 2025. p. 258-82.
[92] Sharma A, Khar S. Conceptualization and development of a semi-automatic vegetable transplanter prototype for small landholdings. Heliyon. 2024;10(11).
[93] Janarth S, Kumar DP. Applications of drones in sustainable horticulture. In: Compendium of horticultural sciences. 2022. p. 104.
[94] Singh S. Application of drone technology used in horticulture crop. 2023.
[95] Gammanpila HW, Sashika MN, Priyadarshani SVG. Advancing horticultural crop loss reduction through robotic and AI technologies: innovations, applications, and practical implications. Adv Agric. 2024;2024(1):2472111.
[96] Gupta N, Gupta PK. Robotics and artificial intelligence (AI) in agriculture with major emphasis on food crops. In: Digital agriculture: a solution for sustainable food and nutritional security. Singapore: Springer; 2024. p. 577-605.
[97] Kumari K, Mirzakhani Nafchi A, Mirzaee S, Abdalla A. AI-driven future farming: achieving climate-smart and sustainable agriculture. AgriEngineering. 2025;7(3).
[98] Javaid M, Haleem A, Khan IH, Suman R. Understanding the potential applications of artificial intelligence in agriculture sector. Adv Agrochem. 2023;2(1):15-30.
[99] Getahun S, Kefale H, Gelaye Y. Application of precision agriculture technologies for sustainable crop production and environmental sustainability: a systematic review. Sci World J. 2024;2024(1):2126734.
[100] Varella WA, Oliveira Neto GC, Stefani E, Costa I, Monteiro RC, Conde W, et al. Integrated service architecture to promote the circular economy in Agriculture 4.0. Sustainability. 2024;16(6):2535.

[101] Lastochkina O, Aliniaeifard S, SeifiKalhor M, Bosacchi M, Maslennikova D, Lubyanova A. Novel approaches for sustainable horticultural crop production: advances and prospects. Horticulturae. 2022;8(10):910.
[102] Nandwani D, editor. Sustainable horticultural systems: issues, technology and innovation. Vol. 2. Cham: Springer; 2014.
[103] Indurthi S, Sarma I, Vinod DV. Horticultural innovations elevating crop yields and agricultural sustainability for a flourishing future. Plant Cell Biotechnol Mol Biol. 2024;25(1-2):22-44.
[104] Iddio E, Wang L, Thomas Y, McMorrow G, Denzer A. Energy efficient operation and modeling for greenhouses: a literature review. Renew Sustain Energy Rev. 2020; 117:109480.
[105] Mohagheghi A. Intelligent control and monitoring for energy-efficient horticultural lighting. 2022.
[106] Mehta A, Yadav A, Kumar A, Kumari K. Waste utilization in horticulture: an overview. J Exp Agric Int. 2024;46(5):742-9.
[107] Ferreira CS, Soares PR, Guilherme R, Vitali G, Boulet A, Harrison MT, et al. Sustainable water management in horticulture: problems, premises, and promises. Horticulturae. 2024;10(9):951.
[108] Singh N, Sharma RL, Yadav K. Sustainable development by carbon emission reduction and its quantification: an overview of current methods and best practices. Asian J Civ Eng. 2023;24(8):3797-822.
[109] Suresh P, Paul A, Kumar BA, Ramalakshmi D, Dillibabu SP, Boopathi S. Strategies for carbon footprint reduction in advancing sustainability in manufacturing. In: Environmental applications of carbon-based materials. Hershey (PA): IGI Global; 2024. p. 317-50.
[110] Ntinas GK, Dannehl D, Schuch I, Rocksch T, Schmidt U. Sustainable greenhouse production with minimised carbon footprint by energy export. Biosyst Eng. 2020; 189:164-78.
[111] Studman CJ. Agricultural and horticultural engineering: principles, models, systems and techniques. Oxford: Butterworth-Heinemann; 2013.
[112] Sultan M. Emerging agricultural engineering sciences, technologies, and applications. AgriEngineering. 2024;6(3):2057-66.
[113] Kumar D, Choudhary V, Kumar N, Jyoti B, Mandal S, Jeet P, et al. Robots for harvesting of horticultural crop: a review: harvesting fruits by robots. J AgriSearch. 2024;11(3):152-64.
[114] Ashaq M, Upadhyay L, Jena L, Kumar V, Jaiswal S, Das J, et al. Drones for monitoring soil moisture and optimizing irrigation scheduling in horticultural farms. J Sci Res Rep. 2024;30(11):1118-35.
[115] Karunathilake EMBM, Le AT, Heo S, Chung YS, Mansoor S. The path to smart farming: innovations and opportunities in precision agriculture. Agriculture. 2023;13(8):1593.
[116] Mishra PN, Gaikwad V, Bansode R, Dhawan MA, Bagul MR, Shaikh MA. A review on precision agriculture: leveraging variable rate application and machine learning for sustainable and profitable farming. Int J Environ Sci. 2025;11(4s):180-8.

[117] Poenaru MM, Manta LF, Gherțescu C, Manta AG. Shaping the future of horticulture: innovative technologies, artificial intelligence, and robotic automation through a bibliometric lens. Horticulturae. 2025;11(5):449.
[118] Misra NN, Dixit Y, Al-Mallahi A, Bhullar MS, Upadhyay R, Martynenko A. IoT, big data, and artificial intelligence in agriculture and food industry. IEEE Internet Things J. 2020;9(9):6305-24.
[119] Chamara N, Islam MD, Bai GF, Shi Y, Ge Y. Ag-IoT for crop and environment monitoring: past, present, and future. Agric Syst. 2022; 203:103497.
[120] Pathania J, Verma P, Bodh S, Da S. Role of robotics and artificial intelligence in horticulture for sustainable resource development: a review. Environ Eng Manag J. 2025;24(1).