



Application of neural networks in the prediction of the circular economy level in agri-food chains

E. G. Muñoz-Grillo^a, N. Sablón-Cossío^b, S. del M. Ruiz-Cedeño^c, A. J. Acevedo-Urquiaga^{d,*}, D. A. Verduga-Alcívar^a, D. Marrero-González^e, K. Diéguez-Santana^f

^a Universidad Técnica de Manabí, Faculty of Basic Sciences, Portoviejo, Ecuador; Doctoral students from the National University of Tumbes, Peru;

^b Universidad Técnica de Manabí, Grupo de Producción y Servicios, Faculty of Postgraduate, Portoviejo, Ecuador;

^c Universidad Técnica de Manabí, Faculty of Administrative and Economic Sciences, Portoviejo, Ecuador; Doctoral students from the National University of Tumbes, Peru;

^d Fundación Universitaria San Mateo, Industrial Engineering Program, Bogotá, Colombia;

^e Universidad Técnica de Manabí, Portoviejo, Ecuador;

^f Universidad Regional Amazónica, IKIAM, Ecuador

References

- [1] M. Hamam et al., "Circular economy models in agro-food systems: A review," *Sustainability*, vol. 13, no. 6, p. 3453, 2021, doi: 10.3390/su13063453.
- [2] Ellen MacArthur Foundation, "Circular Economy Introduction.," 2021. [Online]. Available: <https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview> [Accessed: 15-Jan-2023].
- [3] M. Lieder, F. Asif, A. Rashid, A. Mihelič, and S. Kotnik, "Towards circular economy implementation in manufacturing systems using a multi-method simulation approach to link design and business strategy," *The International Journal of Advanced Manufacturing Technology*, vol. 93, no. 5, pp. 1953-1970, 2017, doi: 10.1007/s00170-017-0610-9.
- [4] P. C. Pandey, "Circular Designing and Green Growth: Insights on Future of Sustainability," *Vision*, vol. 24, no. 1, pp. 113-117, 2020, doi: 10.1177/0972262920903904.
- [5] V. Prieto Sandoval, L. E. Torres Guevara, M. Ormazabal, and C. Jaca, "Beyond the circular economy theory: Implementation methodology for industrial SMEs," *Journal of Industrial Engineering and Management*, vol. 14, no. 3, pp. 425-438, 2021, doi: 10.3926/jiem.3413.
- [6] R. De Angelis, M. Howard, and J. Mienczyk, "Supply chain management and the circular economy: towards the circular supply chain," *Production Planning & Control*, vol. 29, no. 6, pp. 425-437, 2018, doi: 10.1080/09537287.2018.1449244.
- [7] T. Roy, J. A. Garza-Reyes, V. Kumar, A. Kumar, and R. Agrawal, "Redesigning traditional linear supply chains into circular supply chains-A study into its challenges," *Sustainable Production and Consumption*, vol. 31, pp. 113-126, 2022, doi: 10.1016/j.spc.2022.02.004.
- [8] P. Rijal, P. Bras, S. Garrido, J. Matias, C. Pimentel, and H. Carvalho, "Residual Forestry Biomass Supply Chain: A Mapping Approach," *Int J Ind Eng Manag*, vol. 14, no. 3, pp. 244 - 256, 2023, doi: 10.24867/IJIEM-2023-3-336.
- [9] F. Jia, S. Yin, L. Chen, and X. Chen, "The circular economy in the textile and apparel industry: A systematic literature review," *Journal of Cleaner Production*, vol. 259, p. 120728, 2020, doi: 10.1016/j.jclepro.2020.120728.
- [10] E. G. Muñoz, F. O. Cedeño, S. M. Ruiz, and J. C. Cruz, "Aplicación de redes neuronales para predecir el éxito de la compra de deuda a una entidad financiera," *Revista Espacios*, vol. 40, no. 20, 2019. [Online]. Available: <https://www.revistaespacios.com/a19v40n20/19402006.html>. [Accessed: 1-Jun-2023].
- [11] E. G. Muñoz, N. S. Cossío, S. d. M. R. Cedeño, S. E. L. Ricardo, Y. C. Hernández, and E. O. Crespo, "Application of neural networks in predicting the level of integration in supply chains," *Journal of Industrial Engineering and Management*, vol. 13, no. 1, pp. 120-132, 2020, doi: 10.3926/jiem.3051.
- [12] K. Diéguez-Santana, G. Rodríguez Rudi, A. J. Acevedo Urquiaga, E. Muñoz, and N. Sablón-Cossío, "An assessment tool for the evaluation of circular economy implementation," *Academia Revista Latinoamericana de Administración*, vol. 34, no. 2, pp. 316-328, 2021, doi: 10.1108/ARLA-08-2020-0188.

- [13] N. J. Bartie, Y. L. Cobos-Becerra, M. Fröhling, R. Schlatmann, and M. A. Reuter, "The resources, exergetic and environmental footprint of the silicon photovoltaic circular economy: Assessment and opportunities," *Resources, Conservation and Recycling*, vol. 169, 105516, 2021, doi: 10.1016/j.resconrec.2021.105516.
- [14] Z. Ding, Z. Chen, J. Liu, F. Evrendilek, Y. He, and W. Xie, "Co-combustion, life-cycle circularity, and artificial intelligence-based multi-objective optimization of two plastics and textile dyeing sludge," *Journal of Hazardous Materials*, vol. 426, 128069, 2022, doi: 10.1016/j.jhazmat.2021.128069.
- [15] A. Garg, I. Wani, and V. Kushvaha, "Application of Artificial Intelligence for Predicting Erosion of Biochar Amended Soils," *Sustainability (Switzerland)*, vol. 14, no. 2, 684, 2022, doi: 10.3390/su14020684.
- [16] S. Wen, H. Zou, J. Liu, D. E. Evrendilek, Y. Yan, and G. Liang, "Multi-response optimization toward efficient and clean (co-) combustions of textile dyeing sludge and second-generation feedstock," *Journal of Hazardous Materials*, vol. 408, 124824, 2021, doi: 10.1016/j.jhazmat.2020.124824.
- [17] X. J. Luo and L. O. Oyedele, "Forecasting building energy consumption: Adaptive long-short term memory neural networks driven by genetic algorithm," *Advanced Engineering Informatics*, vol. 50, 101857, 2021, doi: 10.1016/j.aei.2021.101857.
- [18] L. Li, S. Yuan, Y. Teng, and J. Shao, "A study on sustainable consumption of fuel—An estimation method of aircraft," *Energies*, vol. 14, no. 22, 7559, 2021, doi: 10.3390/en14227559.
- [19] V. V. Joshi, G. Swaminathan, and S. S. Prabhakaran, "Life cycle assessment of the co-combustion system of single-use plastic waste and lignite coal to promote circular economy," *Journal of Cleaner Production*, vol. 329, 129579, 2021, doi: 10.1016/j.jclepro.2021.129579.
- [20] H. Alhazmi, S. A. R. Shah, and M. A. Basheer, "Performance evaluation of road pavement green concrete: An application of advance decision-making approach before life cycle assessment," *Coatings*, vol. 11, no. 1, pp. 1-18, 2021, doi: 10.3390/coatings11010074.
- [21] S. L. N. Alonso, R. F. R. Forradellas, O. P. Morell, and J. Jorge-Vazquez, "Digitalization, circular economy and environmental sustainability: The application of artificial intelligence in the efficient self-management of waste," *Sustainability*, vol. 13, no. 4, pp. 1-20, 2021, doi: 10.3390/su13042092.
- [22] A. Dashti et al., "Review of higher heating value of municipal solid waste based on analysis and smart modelling," *Renewable and Sustainable Energy Reviews*, vol. 151, 111591, 2021, doi: 10.1016/j.rser.2021.111591.
- [23] F. Facchini, L. Ranieri, and M. Vitti, "A neural network model for decision-making with application in sewage sludge management," *Applied Sciences (Switzerland)*, vol. 11, no. 12, 5434, 2021, doi: 10.3390/app11125434.
- [24] A. N. Matheri, F. Ntuli, J. C. Ngila, T. Seodigeng, and C. Zvinowanda, "Performance prediction of trace metals and cod in wastewater treatment using artificial neural network," *Computers and Chemical Engineering*, vol. 149, 107308, 2021, doi: 10.1016/j.compchemeng.2021.107308.
- [25] W. Lu, J. Lou, C. Webster, F. Xue, Z. Bao, and B. Chi, "Estimating construction waste generation in the Greater Bay Area, China using machine learning," *Waste Management*, vol. 134, pp. 78-88, 2021, doi: 10.1016/j.wasman.2021.08.012.
- [26] H. Khayyam et al., "Improving energy efficiency of carbon fiber manufacturing through waste heat recovery: A circular economy approach with machine learning," *Energy*, vol. 225, 120113, 2021, doi: 10.1016/j.energy.2021.120113.
- [27] Y. Kazançoglu, M. Sağnak, Ç. Lafci, S. Luthra, A. Kumar, and C. Taçoğlu, "Big data-enabled solutions framework to overcoming the barriers to circular economy initiatives in healthcare sector," *International Journal of Environmental Research and Public Health*, vol. 18, no. 14, 7513, 2021, doi: 10.3390/ijerph18147513.
- [28] E. T. Assunção et al., "Peaches Detection Using a Deep Learning Technique—A Contribution to Yield Estimation, Resources Management, and Circular Economy," *Climate*, vol. 10, no. 2, 11, 2022, doi: 10.3390/cli10020011.
- [29] M. Sow, J. Hot, C. Tribout, and M. Cyr, "Improving circular economy by the valorization of non-conventional coal fly ashes in composite cement manufacturing," *Construction and Building Materials*, vol. 300, 124053, 2021, doi: 10.1016/j.conbuildmat.2021.124053.
- [30] J. D. Lau Hiu Hoong, J. Lux, P. Y. Mahieux, P. Turcet, and A. Ait-Mokhtar, "Classification of Recycled Aggregates Using Deep Learning," *RILEM Bookseries*, vol. 35, pp. 21-32, 2021.
- [31] S. P. S.P. and G. Swaminathan, "Thermogravimetric study of textile lime sludge and cement raw meal for co-processing as alternative raw material for cement production using response surface methodology and neural networks," *Environmental Technology and Innovation*, vol. 25, 102100, 2022, doi: 10.1016/j.eti.2021.102100.
- [32] A. Basia, Z. Simeu-Abazi, E. Gascard and P. Zwolinski, "Comparison of data driven algorithms for SoH estimation of Lithium-ion batteries," in 2021 International Conference on Control, Automation and Diagnosis (ICCAD), Grenoble, France, 2021, pp. 1-6, doi: 10.1109/ICCAD52417.2021.9638757.
- [33] A. B. Culaba et al., "Smart sustainable biorefineries for lignocellulosic biomass," *Bioresource Technology*, vol. 344, 126215, 2022, doi: 10.1016/j.biortech.2021.126215.
- [34] D. Sidiras, D. Politi, G. Giakoumakis, and I. Salapa, "Simulation and optimization of organosolv based lignocellulosic biomass refinery: A review," *Bioresource Technology*, vol. 343, 126158, 2022, doi: 10.1016/j.biortech.2021.126158.
- [35] I. H. V. Gue, R. R. Tan, and A. T. Ubando, "Causal network maps of urban circular economies," *Clean Technologies and Environmental Policy*, vol. 24, no. 1, pp. 261-272, 2022, doi: 10.1007/s10098-021-02117-9.
- [36] H. Shabanpour, S. Yousefi, and R. Farzipoor Saen, "Forecasting sustainability of supply chains in the circular economy context: a dynamic network data envelopment analysis and artificial neural network approach," *Journal of Enterprise Information Management*, 2021, doi: 10.1108/JEIM-12-2020-0494.
- [37] C. Liu, "Evaluation Model of Low-Carbon Circular Economy Coupling Development in Forest Area Based on Radial Basis Neural Network," *Complexity*, vol. 2021, 6692792, 2021, doi: 10.1155/2021/6692792.
- [38] K. T. Lee, J. T. Du, W. H. Chen, A. T. Ubando, and K. T. Lee, "Green additive to upgrade biochar from spent coffee grounds by torrefaction for pollution mitigation," *Environmental Pollution*, vol. 285, 117244, 2021, doi: 10.1016/j.envpol.2021.117244.
- [39] Z. Gong, K. Guo, and X. He, "Corporate Social Responsibility Based on Radial Basis Function Neural Network Evaluation Model of Low-Carbon Circular Economy Coupled Development," *Complexity*, vol. 2021, 5592569, 2021, doi: 10.1155/2021/5592569.
- [40] A. Fetanat, M. Tayebi, and G. Shafipour, "Management of waste electrical and electronic equipment based on circular economy strategies: navigating a sustainability transition toward waste management sector," *Clean Technologies and Environmental Policy*, vol. 23, no. 2, pp. 343-369, 2021, doi: 10.1007/s10098-020-02006-7.

- [41] Y. Kazancoglu, M. Sagnak, S. K. Mangla, M. D. Sezer, and M. O. Pala, "A fuzzy based hybrid decision framework to circularity in dairy supply chains through big data solutions," *Technological Forecasting and Social Change*, vol. 170, 120927, 2021, doi: 10.1016/j.techfore.2021.120927.
- [42] N. M. Bocken, I. De Pauw, C. Bakker, and B. Van Der Grinten, "Product design and business model strategies for a circular economy," *Journal of industrial and production engineering*, vol. 33, no. 5, pp. 308-320, 2016, doi: 10.1080/21681015.2016.1172124.
- [43] K. Diéguez-Santana, L. B. Sarduy-Pereira, N. Sablón-Cossío, H. Bautista-Santos, F. Sánchez-Galván, and S. d. M. Ruíz Cedeño, "Evaluation of the Circular Economy in a Pitahaya Agri-Food Chain," *Sustainability*, vol. 14, no. 5, 2022, doi: 10.3390/su14052950.
- [44] J. Brändström and M. Saidani, "Comparison between circularity metrics and LCA: A case study on circular economy strategies," *Journal of Cleaner Production*, vol. 371, p. 133537, 2022, doi: 10.1016/j.jclepro.2022.133537.
- [45] F. Binet, F. Saunier, and M. Margni, "Assessing the Mitigation Potential of Environmental Impacts From Circular Economy Strategies on an Industrial Sector and Its Value Chain: A Case Study on the Steel Value Chain in Quebec," *Frontiers in Sustainability*, vol. 2, 2021, doi: 10.3389/frsus.2021.738890.
- [46] J. U. Ahmed, Q. T. Islam, A. Ahmed, and S. B. Amin, "Extending Resource Value-Based Circular Economy Business Model in Emerging Economies: Lessons from India," (in English), *Business Perspectives and Research*, vol. 11, no. 2, pp. 309-321, 2022, doi: 10.1177/22785337211070363.
- [47] A. Fontana et al., "Circular Economy Strategies for Equipment Lifetime Extension: A Systematic Review," *Sustainability*, vol. 13, no. 3, doi: 10.3390/su13031117.
- [48] J. Monteiro and J. Barata, "Artificial Intelligence in Extended Agri-Food Supply Chain: A Short Review Based on Bibliometric Analysis," *Procedia Computer Science*, vol. 192, pp. 3020-3029, 2021, doi: 10.1016/j.procs.2021.09.074.
- [49] M. Lezoche, J. E. Hernandez, M. d. M. E. Alemany Díaz, H. Panetto, and J. Kacprzyk, "Agri-food 4.0: A survey of the supply chains and technologies for the future agriculture," *Computers in Industry*, vol. 117, p. 103187, 2020, doi: 10.1016/j.compind.2020.103187.
- [50] F. Ciccullo, R. Cagliano, G. Bartezzaghi, and A. Perego, "Implementing the circular economy paradigm in the agri-food supply chain: The role of food waste prevention technologies," *Resources, Conservation and Recycling*, vol. 164, p. 105114, 2021, doi: 10.1016/j.resconrec.2020.105114.
- [51] S. Coulibaly, B. Kamsu-Foguem, D. Kamissoko, and D. Traore, "Deep neural networks with transfer learning in millet crop images," *Computers in Industry*, vol. 108, pp. 115-120, 2019, doi: 10.1016/j.compind.2019.02.003.
- [52] H. Panetto, M. Lezoche, J. E. Hernandez Hormazabal, M. del Mar Eva Alemany Diaz, and J. Kacprzyk, "Special issue on Agri-Food 4.0 and digitalization in agriculture supply chains - New directions, challenges and applications," *Computers in Industry*, vol. 116, p. 103188, 2020, doi: 10.1016/j.compind.2020.103188.
- [53] C. Liu, T. Shu, S. Chen, S. Wang, K. K. Lai, and L. Gan, "An improved grey neural network model for predicting transportation disruptions," *Expert Systems with Applications*, vol. 45, pp. 331-340, 2016, doi: 10.1016/j.eswa.2015.09.052.
- [54] M. K. Adeyeri, S. P. Ayodeji, E. O. Olutomiola, and O. J. Abayomi, "The Automated Process Control Model for Energy Consumption Optimization within Plantain Flour Processing Facility," *Int J Ind Eng Manag*, vol. 13, no. 3, pp. 206-214, 2022, doi: 10.24867/IJIEM-2022-3-313.
- [55] F. C. Ribeiro, F. M. Borém, G. S. Giomo, R. R. De Lima, M. R. Malta, and L. P. Figueiredo, "Storage of green coffee in hermetic packaging injected with CO₂," *Journal of Stored Products Research*, vol. 47, no. 4, pp. 341-348, 2011, doi: 10.1016/j.jspr.2011.05.007.
- [56] R. Sharma, S. S. Kamble, A. Gunasekaran, V. Kumar, and A. Kumar, "A systematic literature review on machine learning applications for sustainable agriculture supply chain performance," *Computers & Operations Research*, vol. 119, p. 104926, 2020, doi: 10.1016/j.cor.2020.104926.
- [57] B. M. Boshkoska et al., "A decision support system for evaluation of the knowledge sharing crossing boundaries in agri-food value chains," *Computers in Industry*, vol. 110, pp. 64-80, 2019, doi: 10.1016/j.compind.2019.04.012.
- [58] F. S. Montero-Vega, C. S. Molina-Cedeño, B. M. Pillco-Herrera, L. B. Sarduy-Pereira, and K. Diéguez-Santana, "Evaluación del impacto ambiental de la construcción de una planta de tratamiento de aguas residuales. Caso río Pindo Chico, Puyo, Pastaza, Ecuador," *Ciencia, Ambiente y Clima*, vol. 3, no. 1, pp. 23-39, 2020, doi: 10.22206/cac.2020.v3i1.pp23-39.
- [59] T. P. Ramos-Ramos, D. J. Guevara-Llerena, L. B. Sarduy-Pereira, and K. Diéguez-Santana, "Producción más limpia y ecoeficiencia en el procesado del cacao: un caso de estudio en ecuador," *Investigación & Desarrollo*, vol. 20, pp. 135-146, 2020.
- [60] K. D. Santana, A. A. Z. Velin, K. L. V. Quijano, and L. B. S. Pereira, "Evaluación del impacto ambiental del cultivo de la pitahaya, Cantón Palora, Ecuador," *TecnoLógicas*, vol. 23, no. 49, pp. 113-128, 2020, doi: 10.22430/22565337.1621.
- [61] Carbono Neutral. "Programa Ecuador Carbono Cero (PECC)." [Online]. Available: <https://carbononeutral.com.ec/programa-ecuador-carbono-cero/> [Accessed: 14-Jan-2024].