BÖLÜM 1

AKUAKÜLTÜRDE DİJİTALLEŞME VE VERİ TABANLI YÖNETİM: SÜRDÜRÜLEBİLİRLİK, TEKNOLOJİ ENTEGRASYONU VE KÜRESEL EĞİLİMLER

Mustafa Tolga TOLON[1]

GİRİŞ

Su ürünleri sektörü, son yıllarda artan tüketim talepleri ve çevresel sürdürülebilirlik gereklilikleri ile zorlu bir döneme girmiştir. Küresel talep karşısında balık ve diğer su ürünleri doğal stoklarının sürdürülebilirliği üzerinde gittikçe artan risk, yetiştiricilik üretimini sektörel odak haline getirmektedir. Bu süreçte, geleneksel üretim yöntemlerinin ötesinde teknolojik yeniliklerin sektöre entegre edilmesi, verimliliği artırmak ve kaynakları daha etkili bir şekilde kullanmak adına büyük bir önem taşımaktadır.

Dünya yetiştiricilik üretimi ilk kez 2022 yılında avcılığı geçerek su ürünleri üretiminin %51'ini oluşturmuş, en güncel verilere göre 2023 yılında 136,2 milyon ton ile avcılık üretiminin (91,7 milyon ton) üzerindeki üretim potansiyelini korumuştur. Toplam su ürünleri üretimi içerisindeki payı ise %59,75'e ulaşmıştır (1).

17.yüzyılda başlayan sanayi devrimi 1950'lerden itibaren bilgisayarlar, elektronik sistemler, otomasyon ve 1960' da ilk internetin doğuşu ile farklı bir sürece evrilerek Endüstri 4.0 olarak adlandırılan dördüncü sanayi devrimi ile devam etmiştir. İçinde bulunduğumuz 21. yüzyılda ise sanayi devrimi yerini dijital devrime bırakmış, hayatın her alanına giren yapay zekâ, makine öğrenmesi, otomasyon, mobil teknolojiler, 5G, nesnelerin interneti (IoT), blokzincir, sanal gerçeklik ve artırılmış gerçeklik teknolojilerinin kullanımı ile gerçek anlamda "Teknoloji Yüzyılı" hayata geçirilmiştir.

[1] Doç. Dr., Ege Üniversitesi Su Ürünleri Fakültesi,Su Ürünleri Yetiştiriciliği Bölümü, tolga.tolon@ege.edu.tr, ORCID iD: 0000-0002-2233-0663

DOI: 10.37609/akya.3872.c1623

Gelecekteki dönüşümün başarısı, büyük veri ve yapay zekâ temelli karar destek sistemlerinin kurulmasına, internet şirketleri ile üreticiler arasında veri analizi ve öngörücü modelleme iş birliklerinin geliştirilmesine bağlıdır. Hükümetlerin uzaktan algılama ve derin öğrenme teknolojileriyle kaynakları izleyerek bilimsel yönetim stratejileri geliştirmesi, bu süreci destekleyecektir. Ayrıca blokzincir, IoT ve izlenebilirlik teknolojilerinin tedarik zincirine entegrasyonu, ürün kalitesi ve güvenliğini artırarak tüketici güvenini güçlendirecektir. Çin'in bu alandaki ilerlemeleri, dijital zekânın kaynak verimliliği ve sürdürülebilirlik üzerindeki etkisini göstermekte; uluslararası iş birlikleri ve veri paylaşım platformları ise diğer ülkeler için uyarlanabilir modeller sunmaktadır.

KAYNAKLAR

1. FAO. Global Aquaculture Production: United Nations, Food and Agriculture Organization; 2025 [updated 28.09.2025. Available from: http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en.
2. Mustapha UF, Alhassan AW, Jiang DN, Li GL. Sustainable aquaculture development: a review on the roles of cloud computing, internet of things and artificial intelligence (CIA). Reviews in Aquaculture. 2021;13(4):2076-91.
3. Liao Y, Deschamps F, Loures EdFR, Ramos LFP. Past, present and future of Industry 4.0-a systematic literature review and research agenda proposal. International journal of production research. 2017;55(12):3609-29.
4. Pratiwy FM, Cahya MD, Andriani Y. Digitization of aquaculture: A review. International Journal of Fisheries and Aquatic Studies. 2022;10(1):18-22.
5. Le T. 7 top digital farming innovations impacting aquaculture: Alltech; 2020 [Available from: https://www.alltech.com/blog/7-top-digital-farming-innovations-impacting-aquaculture.
6. Costantino J. Aquaculture & artificial intelligence: A brief history. Manolin Aqua Blog2024 [Available from: https://blog.manolinaqua.com/en/aquaculture-artificial-intelligence-history.
7. Chen T. How to become data-driven in aquaculture Manolin Aqua Blog2024 [Available from: https://blog.manolinaqua.com/en/how-to-become-data-driven-in-aquaculture.
8. Brennan N. How digitalization improves aquaculture management. Manolin Aqua Blog2024 [Available from: https://blog.manolinaqua.com/en/how-digitalization-improves-aquaculture-management.
9. Andriani Y, Nurhayati A, Zidni I, D Cahya M. Financial Analysis of Costs of Fish Feed Production with Restaurant Waste as Basic Ingredients (Case Study in Jatinangor District, Sumedang Regency, West Java). Asian Journal of Fisheries and Aquatic Research. 2021;14(5):55-60.
10. Sandra MA, Andriani Y, Haetami K, Lili W, Wiyatna M. Effect of adding fermented restaurant waste meal with different concentration to physical quality of fish pellet. Asian Journal of Fisheries and Aquatic Research. 2020;5(3):1-7.
11. Lloyd Chrispin C, Jothiswaran V, Velumani T, Agnes Daney Angela S, Jayaraman R. Application of artificial intelligence in fisheries and aquaculture. Biotica Research Today. 2020;2(6):499-502.
12. Dikel S, Öz M, editors. Artificial intelligence (AI) application in aquaculture. ISPEC 10th Internatıonal Conference on Agriculture, Animal Sciences and Rural Development; 2022.
13. O'donncha F, Grant J. Precision aquaculture. IEEE Internet of Things Magazine. 2019;2(4):26-30.
14. Wang C, Li Z, Wang T, Xu X, Zhang X, Li D. Intelligent fish farm—the future of aquaculture. Aquaculture International. 2021;29(6):2681-711.

15. Rowan NJ. The role of digital technologies in supporting and improving fishery and aquaculture across the supply chain–Quo Vadis? Aquaculture and Fisheries. 2023;8(4):365-74.
16. Flores-Iwasaki M, Guadalupe GA, Pachas-Caycho M, Chapa-Gonza S, Mori-Zabarburú RC, Guerrero-Abad JC. Internet of Things (IoT) Sensors for Water Quality Monitoring in Aquaculture Systems: A Systematic Review and Bibliometric Analysis. AgriEngineering. 2025;7(3):78.
17. Muñoz L, Aspillaga E, Palmer M, Saraiva JL, Arechavala-Lopez P. Acoustic telemetry: a tool to monitor fish swimming behavior in sea-cage aquaculture. Frontiers in Marine Science. 2020;7:645.
18. Vo TTE, Ko H, Huh J-H, Kim Y. Overview of smart aquaculture system: Focusing on applications of machine learning and computer vision. Electronics. 2021;10(22):2882.
19. Fitzgerald A, Ioannou CC, Consuegra S, Dowsey A, García de Leaniz C. Machine vision applications for welfare monitoring in aquaculture: challenges and opportunities. Aquaculture, Fish and Fisheries. 2025;5(1):e70036.
20. Yang L, Liu Y, Yu H, Fang X, Song L, Li D, Chen Y. Computer vision models in intelligent aquaculture with emphasis on fish detection and behavior analysis: a review. Archives of Computational Methods in Engineering. 2021;28(4).
21. Amundsen HB, Caharija W, Pettersen KY. Autonomous ROV inspections of aquaculture net pens using DVL. IEEE Journal of Oceanic Engineering. 2021;47(1):1-19.
22. Verma P, Ranjan D, Sahu A, Kumar D, Verma HS. Automation Technology and Robotics in Fisheries and Aquaculture Sector. Chronicle of Aquatic Science. 2023;1(5):99-104.
23. Huang YP. The Artificial Intelligence of Things and Its Aquaculture Applications. Responsible Seafood Advocate2025 [Available from: https://www.globalseafood.org/advocate/the-artificial-intelligence-of-things-and-its-aquaculture-applications/.
24. Son S, Jeong Y. An automated fish-feeding system based on CNN and GRU neural networks. Sustainability. 2024;16(9):3675.
25. Thornburg J. Feed the fish: A review of aquaculture feeders and their strategic implementation. Journal of the World Aquaculture Society. 2025;56(2):e70016.
26. Saini VP. Smart Fish Feeding System in Aquaculture. Information Technology in Fisheries and Aquaculture. 2025:123.
27. Iniyan Arasu M, Subha Rani S, Thiyagarajan K, Ahilan A. AQUASENSE: aquaculture water quality monitoring framework using autonomous sensors. Aquac Int. 2024;32:9119-35.
28. Olanubi OO, Akano TT, Asaolu OS. Design and development of an IoT-based intelligent water quality management system for aquaculture. Journal of Electrical Systems and Information Technology. 2024;11(1):15.
29. AquaManager. Advanced Aquaculture Software 2025 [Available from: https://www.aqua-manager.com
30. Manolin. Aquaculture Data Intelligence Software 2025 [Available from: https://manolinaqua.com/aquaculture-data-intelligence
31. Li R, Jiang Y, Tang J, Yuan P, He N, editors. Application of VR and AR Technology in Fish Simulation Teaching. International Conference on Computer Science and Educational Informatization; 2023: Springer.
32. Munawar SAH. Virtual Maintenance and Training of Fish Farms through Photogrammetry and VR.: Seafood Innovation Fund; 2025 [Available from: https://www.sustainableaquaculture.com/projects/project-list/virtual-maintenance-and-training-of-fish-farms-through-photogrammetry-and-virtual-reality
33. Adebayo IT, Ajibola S, Ahmad A, Cartujo P, Muritala I, Elegbede IO, et al. Understanding the application of digital technologies in aquaculture supply chains through a systematic literature review. Aquaculture International. 2025;33(6):397.
34. Lahiri B, Anurag TS, Borah S, Marak NR, Pavan Kumar S, Sangma SM, et al. Designing a user-centric mobile-based agro advisory system for sustainable development of smallholder farming systems in the eastern Himalayas, India. Information Technology for Development. 2024;30(4):665-95.

35. Reddy M, Rao IS, Srinivasulu M, Kumar GS. Perception and usefulness of mobile phone based agro-advisories (MBAs). International Journal of Current Microbiology and Applied Sciences. 2017;6(7):866-72.
36. Cole SA, Fernando AN. 'Mobile'izing agricultural advice technology adoption diffusion and sustainability. The Economic Journal. 2021;131(633):192-219.
37. Fabregas R, Kremer M, Schilbach F. Realizing the potential of digital development: The case of agricultural advice. Science. 2019;366(6471):eaay3038.
38. Atheequlla G, Mukherjee A, Roy ML, Chandra N. Mobile based agro advisory service and farmer's willingness to pay: A case study in Bageshwar District of Uttarakhand. Journal of Community Mobilization and Sustainable Development. 2021;16(3):976-86.
39. Engle CR, Kumar G, van Senten J. Cost drivers and profitability of US pond, raceway, and RAS aquaculture. Journal of the World Aquaculture Society. 2020;51(4):847-73.
40. Edwards P, Zhang W, Belton B, Little DC. Misunderstandings, myths and mantras in aquaculture: Its contribution to world food supplies has been systematically over reported. Marine Policy. 2019;106:103547.
41. Foroughi A. Supply chain workforce training: addressing the digital skills gap. Higher Education, Skills and Work-Based Learning. 2021;11(3):683-96.
42. Kobayashi M, Msangi S, Batka M, Vannuccini S, Dey MM, Anderson JL. Fish to 2030: the role and opportunity for aquaculture. Aquacult Econ Manag. 2015;19(3):282-300.
43. Alsaleh M, Wang X, Nan Z. Evaluating the Potential of Information and Communication Technologies to Increase Aquaculture Sustainability. Sustainable Development. 2025;33(3):3663-80.
44. Barreto MO, Rey Planellas S, Yang Y, Phillips C, Descovich K. Emerging indicators of fish welfare in aquaculture. Reviews in Aquaculture. 2022;14(1):343-61.
45. Kunzmann A, Todinanahary G, Msuya FE, Alfiansah Y. Comparative environmental impacts and development benefits of coastal aquaculture in three tropical countries: Madagascar, Tanzania and Indonesia. Tropical Life Sciences Research. 2023;34(3):279.
46. Lan H-Y, Ubina NA, Cheng S-C, Lin S-S, Huang C-T. Digital twin architecture evaluation for intelligent fish farm management using modified analytic hierarchy process. Applied Sciences. 2022;13(1):141.
47. Sung W-T, Isa IGT, Hsiao S-J. Designing aquaculture monitoring system based on data fusion through deep reinforcement learning (DRL). Electronics. 2023;12(9):2032.
48. Aung T, Abdul Razak R, Rahiman Bin Md Nor A. Artificial intelligence methods used in various aquaculture applications: A systematic literature review. Journal of the World Aquaculture Society. 2025;56(1):e13107.
49. Meng D, Yang X, Wang Z, Liu Y, Zhang J, Liu X, Liu B. Spatial Distribution and Differentiation Analysis of Coastal Aquaculture in China Based on Remote Sensing Monitoring. Remote Sensing. 2024;16(9):1585.
50. Ottinger M, Bachofer F, Huth J, Kuenzer C. Mapping aquaculture ponds for the coastal zone of Asia with Sentinel-1 and Sentinel-2 time series. Remote Sensing. 2021;14(1):153.
51. Roalkvam I, Drønen K, Dahle H, Wergeland HI. A case study of biofilter activation and microbial nitrification in a marine recirculation aquaculture system for rearing Atlantic salmon (Salmo salar L.). Aquaculture Research. 2021;52(1):94-104.
52. Lima AC, Royer E, Bolzonella M, Pastres R. Digital twins for land-based aquaculture: A case study for rainbow trout (Oncorhynchus mykiss). Open Research Europe. 2023;2:16.
53. Antony AP, Leith K, Jolley C, Lu J, Sweeney DJ. A review of practice and implementation of the internet of things (IoT) for smallholder agriculture. Sustainability. 2020;12(9):3750.
54. Aghaji UV, Benjamin EO, Buchenrieder G. Digitalization in small-scale urban recirculation aquaculture: Data analytics in Sub-Saharan Africa. 2023.
55. Benjamin EO, Ola O, Buchenrieder GR. Technology-Business-Management of Recirculating Aquaculture System (RAS) for Sustainable Urban Farming in Sub-Saharan Africa: A Review of Challenges and Opportunities. 2022.
56. Bjelland HV, Folkedal O, Føre HM, Grøtli EI, Holmen IM, Lona E, et al. Exposed aquaculture

operations: Strategies for safety and fish welfare. Reviews in Aquaculture. 2025;17(1):e12964.
57. Yilmaz M, Çakir M, Oral O, Oral MA, Arslan T. Using machine learning technique for disease outbreak prediction in rainbow trout (Oncorhynchus mykiss) farms. Aquaculture Research. 2022;53(18):6721-32.
58. Aydın İ, Öztürk RÇ, Eroldoğan OT, Arslan M, Terzi Y, Yılmaz S, et al. An in-depth analysis of the finfish aquaculture in Türkiye: Current status, challenges, and future prospects. Reviews in Aquaculture. 2025;17(2):e70010.
59. Prasad M, Majeed S, Romichan S, Mathew W, Udaybabu P. Cost effective IoT based automated fish farming system with flood prediction. Int J Adv Trends Comput Sci Eng. 2020;9(1.3 Special Issue):291-7.
60. Yang X, Zhang S, Liu J, Gao Q, Dong S, Zhou C. Deep learning for smart fish farming: applications, opportunities and challenges. Reviews in Aquaculture. 2021;13(1):66-90.
61. Tamer C, Isıdan H, Kalaycı G, Ozan E, Ozkan B, Albayrak H. Determination of VP2 sequence-based virulence motifs and phylogenetic analysis of domestic Turkish IPNV ısolates. Journal of fish diseases. 2022;45(2):327-34.
62. Cisar P, Bekkozhayeva D, Movchan O, Saberioon M, Schraml R. Computer vision based individual fish identification using skin dot pattern. Scientific Reports. 2021;11(1):16904.