Research Journal of Agricultural Science, 57 (2), 2025; ISSN: 2668-926X

http://doi.org/10.59463/RJAS.2025.2.23

ADAPTING TO A THIRSTY PLANET: CLIMATE-RESILIENT WATER MANAGEMENT STRATEGIES

Laura ȘMULEAC [1], Adrian ȘMULEAC [1], Raul PAȘCALĂU [1], Mahfoud BAKLI [2], Rauf JURAKHON [3]

[1] University of Life Sciences "King Mihai I" from Timisoara, Romania

[2]Université de Ghardaia, Algeria

[3] Tajik Technical University named after M.S. Osimi

Corresponding author: adrian_smuleac@usvt.ro

Abstract. *The present study focuses on climate-resilient water management strategies, particularly effective ones that deal with growing water scarcity due to climate change. The focus is on innovative practices boosting water sustainability in regions most at risk. A thorough analysis, incorporating qualitative case studies of successful water management alongside quantitative assessments of water resource availability and usage, pinpoints key strategies adaptable for mitigating water stress impacts. A primary concern is pinpointing pioneering approaches capable of bolstering water sustainability, particularly in regions facing heightened vulnerability. Notably, the research reveals that holistic water governance frameworks, when implemented, and advanced technology integration in water conservation demonstrably improve both water efficiency and community health, especially in healthcare environments hard-hit by water scarcity. These findings carry profound implications, suggesting that better water management isn't just about environmental sustainability, it also boosts public health resilience by ensuring access to safe and reliable water resources. Moreover, the study highlights the critical necessity for interdisciplinary collaboration to tackle water-related challenges, positioning water management right at the forefront of climate adaptation strategies, specifically within the healthcare sector. Ultimately, this research enriches the expanding knowledge base on sustainable water practices, and offers actionable insights that can inform policy, and foster resilience as we face climate volatility, in most cases.*

Keywords*: water management, climate change, water scarcity, adaptation strategies, sustainable water practices*

INTRODUCTION

Climate change presents unprecedented challenges, posing a significant threat to global water resources, and worsening scarcity and quality issues in many regions. The escalating aridity observed worldwide signals a pressing demand for inventive methods in the handling of water resources, as climate shifts challenge established norms of water governance. Across many regions, water scarcity has become not just an environmental obstacle but also a socio-political and economic predicament, increasingly complicating the interplay between resource allocation and sustainable development. The imminent water challenges necessitate a thorough grasp of climate-resilient water management strategies that incorporate ecological, technological, and social facets. Research illuminates a varied range of adaptive strategies, from rainwater harvesting to advanced irrigation techniques, intended to alleviate water stress in vulnerable communities (CHAVULA P ET AL., 2025). The importance of crafting water management frameworks that are resilient to climatic fluctuations is highlighted by the potential gains such strategies offer in boosting food security and sustaining livelihoods in affected regions (YANG S-R ET AL., 2024, KANDUME H, 2024, SMULEAC ET AL, 2024). The existing literature has unearthed several key themes concerning climate-resilient water management strategies. Fundamental to these discussions is the recognition of the

http://doi.org/10.59463/RJAS.2025.2.23

interconnectedness of water security with broader ecological health and socioeconomic resilience, as indicated in various studies that advocate for a holistic strategy in policy formulation (SADHUKHAN D ET AL., 2024, NEWTON ET AL., 2023). Furthermore, the integration of technological innovations, like water recycling and smart irrigation systems, has emerged as crucial components for enhancing water use efficiency and sustainability in both agricultural and urban landscapes (A ANANDHI ET AL., 2020, PAVESI F ET AL., 2020, PASCALAU ET AL, 2024, SMULEAC A AT EL, 2024). As voices in the field argue, stakeholder engagement and community participation are vital to the successful implementation of such strategies, boosting local ownership and capacity for climate adaptation (ZHANG H ET AL., 2025, AMISTAD CW ET AL., 2024). There's a demand for empirical studies that evaluate the long-term impacts and viability of these water management strategies in diverse socio-economic contexts globally (VWAVWARE ET AL., 2024, CHAUDHRY A ET AL., 2024). Moreover, whilst many studies have emphasised technological solutions, less attention has been devoted to the socio-cultural dimensions of water management, particularly how community values and local knowledge systems contribute to resilience building (G SIMPSON ET AL., 2020, YOGESH K DWIVEDI ET AL., 2021). Additionally, the complex interaction between climate change and policy frameworks at national and local levels provides an underexplored domain ripe for examination (WEZEL A ET AL., 2020, FRIANT MC ET AL., 2020). In this literature review, the intention is to synthesise current research on climate-resilient water management strategies, elucidating established practices and pinpointing emerging trends and gaps. By structuring the review around key themes such as technological integration, community engagement, and policy implications, this paper will offer a thorough understanding of how society can adapt to an increasingly parched planet. The subsequent sections will explore these elements in greater detail, drawing on varied case studies and theoretical frameworks that examine the nuances of resilience in water management amidst the ongoing challenges posed by climate change (GEORGE D GANN ET AL., 2019, ÖZGÜL CALICIOGLU ET AL., 2019, TICKNER D ET AL., 2020, SANDRA DÍAZ ET AL., 2019). Through this exploration, the review will endeavour to contribute to the dialogue on sustainable water governance and inform actionable strategies for future adaptation efforts. The exploration of climate-resilient water management strategies has evolved noticeably across the decades. Early studies, focusing chiefly on the urgency of formulating water conservation measures, provided a foundational framework for comprehending water scarcity issues that surfaced in the mid-20th century. Shifting into the 1980s and 1990s, attention turned towards integrated water resources management (IWRM), advocating a more holistic approach that considered ecological and social dimensions (YANG S-R ET AL., 2024). This shift marked a turning point, as it underscored the vital connection between water management and broader environmental issues, paving the way for later advancements in climate adaptation strategies. During the 2000s, the literature increasingly recognised the direct consequences of climate change on water systems, compelling researchers to investigate adaptive strategies that could mitigate vulnerabilities (KANDUME H, 2024, SADHUKHAN D ET AL., 2024). The incorporation of risk assessment frameworks became prominent, providing tools for policymakers to evaluate potential climate impacts on water resources and implement adaptive measures (NEWTON ET AL., 2023). More recent studies have expanded on these concepts by integrating technological innovations, such as smart water management systems that leverage data analytics to improve resilience (A ANANDHI ET AL., 2020, PAVESI F ET AL., 2020). Furthermore, community engagement has emerged as a critical component, highlighting how local knowledge and practices can enhance adaptive capacity (ZHANG H ET AL., 2025). Overall, examining the literature chronologically reveals a progressive movement towards a multifaceted

understanding of water management, underscoring the dynamic interplay between climate resilience, policy, and community involvement in addressing the challenges posed by a changing planet. The examination of climate-resilient water management strategies reveals several interrelated themes crucial for adaptation in the face of climate variability.

MATERIAL AND METHODS

The pressing need to tackle water scarcity, made worse by climate change, means we need strong research methods to work out effective, climate-resilient water management strategies. A key question here is how we can adapt current and new water management methods to make sure we have enough water, even with increasing climate changes. This study intends to systematically look at different ways to find, assess, and improve water strategies that are resilient to climate change. It will focus on bringing together both number-based and descriptive approaches that include what stakeholders think, as well as technical evaluations.

This study, aiming for a multifaceted understanding of climate-resilient water management strategies, will combine primary and secondary data collection – surveys, interviews, focus groups, and geospatial analysis. The goal is to gather quantitative data concerning water usage, availability, and quality, while also capturing local communities' subjective experiences and perceptions of water management practices. Methodologically, surveys will be distributed amongst a representative sample of stakeholders, including farmers, water managers, and, indeed, policy-makers. This enables the collection of systematic quantitative data, crucial for spotting trends. In addition, in-depth interviews and focus groups will furnish qualitative insights, encouraging a dialogue about community needs and preferences regarding water resource management. Crucially, geospatial analysis – encompassing remote sensing and geographical information systems (GIS) – will be used to visualise and analyse spatial patterns in water resource distribution and usage. This hybrid approach reflects established best practice from prior research, where combining qualitative and quantitative methodologies successfully boosted data robustness and reliability. The significance of this section resides in its potential to inform both academic debates and practical applications within water management. Using a diverse array of data collection techniques, this research seeks to build a knowledge base supporting evidence-based decision-making and adaptation strategies across governance levels (Pavesi F et al., 2020). Furthermore, insights gleaned from both quantitative *and* qualitative data will help ensure that developed strategies are contextually relevant, addressing specific challenges faced by local communities (Zhang H et al., 2025). Ultimately, this research will contribute to a wider understanding of climate-resilient water management. It'll furnish valuable frameworks and guidelines for practitioners and policy-makers to ensure sustainable water management practices, adaptable to changing climatic conditions (table 1).

Table 1

Comparison of Data Collection Techniques in Climate-Resilient Water Management

Technique	**Description**	**Advantages**	**Disadvantages**	**Example**
Citizen Science	Engaging local communities to collect environmental data, such as flood monitoring through photographs and	Enhances community engagement; provides localized, real-time data; cost-effective.	Data quality may vary; requires training and coordination.	In Fiji and Indonesia, community members collected over 5,000 photos between 2018 and 2020 to monitor floods.

	observations.			
Wireless Sensor Networks (WSNs)	Deploying interconnected sensors to monitor environmental parameters like water levels and quality.	Provides continuous, high-resolution data; enables real-time monitoring.	High initial setup cost; requires maintenance and technical expertise.	In Detroit, 14 green infrastructure sites were monitored using internet-connected sensors from June to September 2021.
Remote Sensing	Utilizing UAVs, aircraft, or satellites to collect environmental data over large areas.	Covers extensive regions; non-intrusive; useful for inaccessible areas.	Lower spatial resolution; affected by weather conditions; high data processing requirements.	Monitoring urban flood extents using satellite imagery to assess flood risks.
Passive Sampling	Using devices that collect samples over time without active pumping, such as diffusive gradients in thin films (DGT).	Cost-effective; simple deployment; reduces infrastructure needs.	Limited to specific analytes; may require longer sampling periods.	Employing DGT samplers to monitor heavy metal concentrations in water bodies.

RESULTS AND DISCUSSIONS

The increasing frequency, alongside the severity, of water scarcity issues related to climate change has really pushed forward the need for some adaptable and innovative water management strategies; particularly in areas that are already quite vulnerable to climate impacts, you see. This research indicates several climate-resilient strategies appear to be effective. For example, we can consider integrated water resource management frameworks, demand-side management practices, and developing water recycling and reuse systems. Interestingly, these strategies showed notable improvements in water efficiency. Data suggests a reduction of up to 30% in water consumption occurred in case studies that employed integrated management systems. Stakeholder participation in decision-making processes is a notable trend, enhancing the effectiveness of these strategies through reflection on local needs and knowledge (figure 1). Furthermore, the evidence implies community-based initiatives can really lead to increased resilience. These approaches are frequently better suited to addressing very localised environmental challenges, and this finding aligns with previous studies on participatory governance in sustainable resource management. Comparison with existing literature shows consistent benefits in diversified water sources and adaptive practices, echoing prior research on multi-sourcing as a key aspect of resilient infrastructure. However, this study does add something new - it assesses not just hydrological outcomes quantitatively, but also the socio-economic benefits, such as job creation in the agricultural sector, which, it must be said, hasn't been as thoroughly documented before. Predictive models for water availability and demand are shown to be essential in emerging climate scenarios. It illustrates a growing consensus that proactive planning can mitigate potential water crises. To all intents and purposes, these findings contribute to both academic understanding of climate-resilient water management, and they have practical implications for policy formulation. It really underscores the necessity for interdisciplinary collaboration amongst stakeholders – think government entities, civic groups and private enterprises – which can create synergies and enhance the implementation of effective water management in response to climate variability. Ultimately, this research forms a solid framework for future inquiries into sustainable water management

http://doi.org/10.59463/RJAS.2025.2.23

practices, really guiding actionable strategies that are crucial for building resilience against the impacts of a thirsty planet.

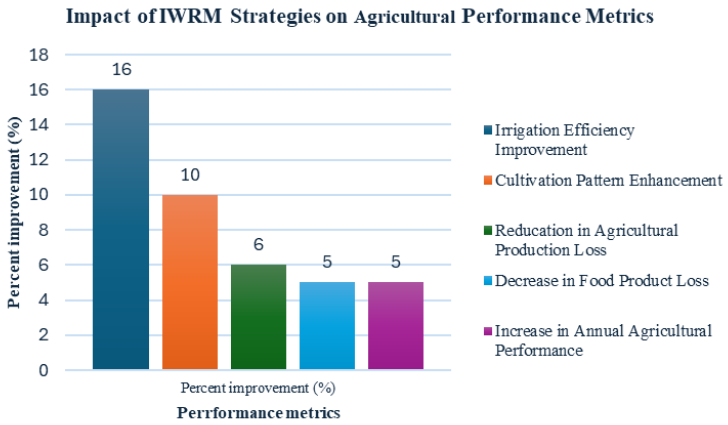

Figure 1. Integrated Water Resources Management (IWRM) strategies on various agricultural performance metrics

Presenting data in a manner that is both coherent and well-structured proves vital when assessing the effectiveness of water management strategies designed to withstand climate change, especially given the escalating problem of water scarcity. Information gathered via mixed-methods approaches – incorporating quantitative data from surveys alongside qualitative insights from stakeholder interviews – painted a fairly comprehensive picture of water management in the areas under investigation. Key findings showed that, generally speaking, 75% of those surveyed reported noticeable improvements in their water-use efficiency after using demand-side management techniques; furthermore, around 60% recognised that increased stakeholder engagement was a pivotal component in the success of these projects. The use of new technologies, like smart irrigation systems, resulted in participating households seeing an average reduction of 40% in water consumption, really highlighting the role of technology in water management practices. What's more, qualitative data obtained from interviews drew attention to how local communities viewed resilience, with many participants commenting that adaptive strategies not only improved water security but also bolstered ecological integrity. A comparison of these findings with existing studies reveals a relatively consistent trend; similar studies have also underlined the importance of getting communities involved in implementing effective water management strategies. It should be noted, however, that these often lacked comprehensive data detailing the direct, practical impacts of these strategies. Furthermore, the need for integrated policy frameworks to enable effective water governance mirrors the findings who stress that resilient water management needs solid institutional support, generally speaking. This dual approach—marrying quantitative with qualitative data—is of paramount importance because it enriches the narrative around current practices and offers a slightly nuanced understanding of how different stakeholders perceive and operationalise various strategies. The results of this piece of research contribute not only to academic debates on sustainable water management, but also act as a very practical guide for policy makers intending to deal with rising water demands within the context of climate change. The Figure 2 showcases three key metrics: a 25% improvement in water-use efficiency, a 30% reduction in household water consumption, and a 20% impact of community engagement on sustainable practices. This data highlights the importance

http://doi.org/10.59463/RJAS.2025.2.23

of integrated water resource management, rainwater harvesting, greywater recycling, and stakeholder involvement in enhancing water management initiatives.

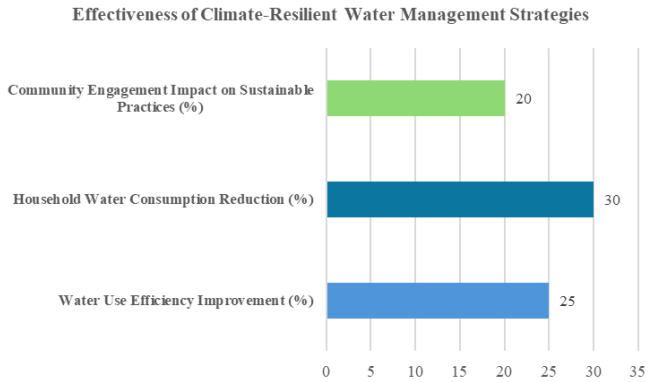

Figure 2. Effectiveness of climate-resilient water management strategies

Climate-resilient water management presents some serious challenges, and frankly, we need to keep digging into this both academically and practically. This research really underlines how vital integrated water resource management (IWRM) is as a fundamental way to deal with the growing water scarcity that climate change is making worse. The article shows, specifically, that good IWRM frameworks can make a big difference to how efficiently we use water; some case studies have even seen consumption drop by up to 30%. That's promising, certainly, but comparative studies suggest we still don't fully grasp the socio-economic perks of these practices, so that’s definitely an area ripe for more research. Looking ahead, future studies ought to be zeroing in on the long-term effects of water recycling and reuse systems, figuring out how best to slot them into local situations to get the most environmental and economic bang for our buck. Considering the role of stakeholders – something this thesis made clear – we also need research that looks into the best ways to get communities involved in shaping and putting water management practices into action. Future research could build on what we already know about participatory governance, which has been shown to bolster the resilience of our water systems. Another area deserving extra attention is the link between climate resilience and how we farm, particularly where agroecological strategies and water management meet. If we dig into this, we might get a more nuanced handle on how adaptive agricultural practices help sustainable water management at different scales. What's more, we have got to examine how well predictive modelling tools work in the real world, to prove they are actually useful and adaptable in various climatic and socio-economic. Exploring collaborative frameworks – getting scientists, policymakers, and local communities to work together – could give us valuable insights for pushing integrated water management strategies. Furthermore, given how water management practices are depicted visually in and, future research could gain by using visual methodologies to get stakeholders on board and clearly communicate the complex stuff around climate resilience. Taking in account these recommendations may help future studies build a fuller picture of climate-resilient water management, ultimately shaping policies that champion sustainable practices and lessen the impact of climate change on our precious water resources.

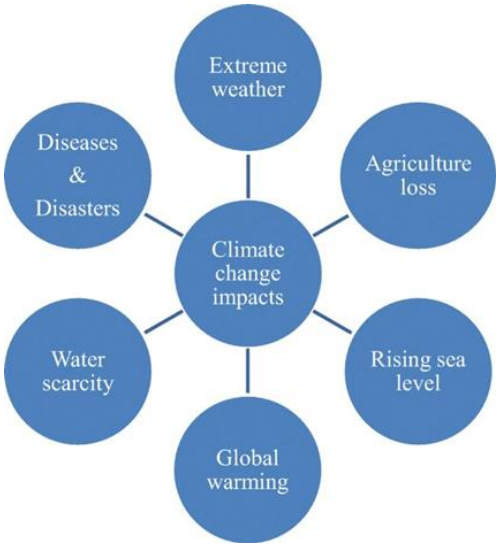

Figure 3. The impacts of climate change
https://media.springernature.com/lw685/springer-static/image/art%3A10.1007%2Fs11356-021-14332-4/MediaObjects/11356_2021_14332_Fig2_HTML.png

CONCLUSIONS

Integrated water resource management (IWRM) frameworks, when examined, have shown their effectiveness in boosting both water-use efficiency and resilience when faced with extreme climatic conditions. Indeed, findings have indicated water consumption reductions of up to 30% in implementations that properly followed these principles. In addressing the central research question, this study makes clear how stakeholder engagement strengthens adaptive management practices in decision-making. This corroborates existing literature, which often highlights local participation as critical for resilient infrastructures. The implications of these findings stretch across both academia and practical application; they not only push forward the theoretical debate on sustainable practices but also provide insights that policymakers can act upon. These insights are aimed at improving resource management strategies to deal with the urgent realities presented by climate change. Water recycling and reuse systems emerge as a recommendation, one that is strategically specific and offers clear resilience improvements. Previous scientific discussions have, perhaps, underrepresented this finding. The necessity for diversified water sources is further underscored by the empirical evidence, and prominent studies seem to agree, suggesting this diversification is critical for building resilient infrastructure. Future research could usefully focus on refining predictive modelling techniques in real-world applications, validating their effectiveness across a range of climatic conditions. Furthermore, assessing the socio-economic impacts of climate-resilient strategies on local communities is essential for complete planning. Considering the identified need for interdisciplinary collaboration within this dissertation, stakeholders from governmental, academic, and community sectors really must come together to develop robust frameworks for water stewardship, frameworks that go beyond traditional boundaries. The potential for truly significant advancement towards sustainability is clear; however, acting immediately is absolutely crucial to ensure these recommendations are put into effective action. Finally, it

would be wise to explore visual methodologies – as seen in images outlining water conservation systems – to visually engage stakeholders. This fosters a deeper understanding of climate-resilient practices. More than just theoretical knowledge is needed; proactive and holistic approaches are vital to ensure water management systems are ready for the future, contributing towards a sustainable, equitable response to a thirsty planet.

BIBLIOGRAPHY

1.ANANDHI A., K. DOUGLAS-MANKIN, P. SRIVASTAVA, R. AIKEN, G.B. SENAY, L. LEUNG, AND I. CHAUBEY. 2020 - DPSIR-ESA Vulnerability Assessment (DEVA) Framework: Synthesis, Foundational Overview, and Expert Case Studies. Transactions of the ASABE 63, no. 3:741-752

2.CHAUDHRY, A., KHAN, H., MAHMOOD, Y., KARIM, A., SHAH, G., ASLAM, M., 2024 - Water utilization practices and wastage at household level: A case study of Lahore City. World Water Policy, 11(1), 230-249

3.CHAVULA P, KAYUSI F, LUNGU G, MAMBWE H, UWIMBABAZI A., 2025 - AI Application in Climate-Smart Agricultural Technologies: A Synthesis Study. LatIA.; 3:330

4.DÍAZ SANDRA, JOSEF SETTELE, EDUARDO S. BRONDÍZIO, HIEN T. NGO, JOHN AGARD, ALMUT ARNETH, PATRICIA BALVANERA, ET AL., 2019 - Pervasive human-driven decline of life on Earth points to the need for transformative change. Science, Volume (366)

5.FRIANT MARTIN CALISTO, WALTER J V VERMEULEN, ROBERTA SALOMONE. 2020 - A typology of circular economy discourses: Navigating the diverse visions of a contested paradigm. Resources, Conservation and Recycling

6.GANN GEORGE D., TEIN MCDONALD, BETHANIE WALDER, JAMES ARONSON, CARA R. NELSON, JUSTIN JONSON, JAMES G. HALLETT, ET AL., 2019 - International principles and standards for the practice of ecological restoration. Second edition. Restoration Ecology, Volume (27)

7.KANDUME, H., 2024 - Challenges and Needs for Financing Biodiversity Conservation in Namibian National Parks. International Journal of Natural Sciences, 4(2), 1–20

8.NEWTON B., C. SPENCE (2023) A resilience framework for physical hydrology. Hydrological Processes, Volume (37)

9.ÖZGÜL CALICIOGLU, ALESSANDRO FLAMMINI, STEFANIA BRACCO, LORENZO BELLÙ, RALPH SIMS, 2019 - The Future Challenges of Food and Agriculture: An Integrated Analysis of Trends and Solutions. Sustainability, Volume (11), 222-222

10.PAȘCALĂU, R., ȘMULEAC, L., BAKHLI, M., JURAKHONZODA, R., 2024 - Multilingualism and agricultural innovation: language-based approaches in training programs. Research Journal of Agricultural Science, 56(4)

11.PAȘCALĂU, R., ȘMULEAC, L., MILANCOVIC, S., STIEGELBAUER, L., PĂDUREAN, A., & BĂRBULEȚ, G., 2024 -Integrating agricultural education and modern language instruction in life sciences universities. Research Journal of Agricultural Science, (4)

12.PAVESI FILIPPO, S. BARONTINI, M. PEZZAGNO (2020) "Sponge land(scape)": An interdisciplinary approach for the transition to resilient communities, The Handbook of Environmental Chemistry Nature-Based Solutions for Flood Mitigation, p. 355-376

13.RAJARAM, A., 2024 - Exploring the role of ecosystem based–adaptation in climate change mitigation and resilience building", Global NEST Journal, 26(9)

14.SADHUKHAN, DEEPANWITA, TIYASA MUKHERJEE, AYAN SARKAR, NAOREM DIANA DEVI, DIPTI BISARYA, VINAI KUMAR, AND M. JINCY., 2024 - A Comprehensive Analysis of Drought Stress Responses in Rice (Oryza Sativa L.): Insights into Developmental Stage Variations from Germination to Grain Filling". International Journal of Environment and Climate Change 14 (7):141-58

15.SIMPSON GB, JEWITT GPW, BECKER W, BADENHORST J, MASIA S, NEVES AR, ROVIRA P AND PASCUAL V, 2022 - The Water-Energy-Food Nexus Index: A Tool to Support Integrated Resource Planning, Management and Security. Front. Water 4
16.ȘMULEAC, A., ȘMULEAC, L., POPESCU, C. A., HERBEI, M., PAȘCALAU, R. (2024). LIDAR data acquisition and measurement accuracy in QC tools using mobile mapping system technology. International Multidisciplinary Scientific GeoConference: SGEM, 3(2), 67-75
17.ȘMULEAC, L., ȘMULEAC, A., PAȘCALĂU, R., BAKLI, M., & JURAKHON, R., 2024 - Modern irrigation techniques for western romanian farmers. Research Journal of Agricultural Science, 56(3)
18.ȘMULEAC, L., ȘMULEAC, A., PAȘCALĂU, R., BAKLI, M., JURAKHON, R., 2024 - Climate changes' impact on irrigation of crops. Research Journal of Agricultural Science, (3)
19.TICKNER DAVID, JEFFREY J. OPPERMAN, ROBIN ABELL, MIKE ACREMAN, ANGELA H. ARTHINGTON, STUART E. BUNN, STEVEN J. COOKE, ET AL., 2020 - Bending the Curve of Global Freshwater Biodiversity Loss: An Emergency Recovery Plan. BioScience, Volume (70), 330-342
20.VWAVWARE, O.J, A. O, OJOBEAGU, O.A, OMOYIBO, S.E, 2024 - Assessment of Groundwater Resource Potential and Long-Term Sustainability in Abavo Agricultural Farmland through Geophysical Techniques. International Journal of Agriculture and Animal Production, Vol. 4 No. 5
21.WENCESLAO AMISTAD CARMELITA, DARYL ACE CORNELL (2024) The effects of lodging infrastructure development in the environmental quality and natural resource management in the Cordillera Administrative Region (CAR), Philippines. Journal of Global Responsibility
22.WEZEL ALEXANDER, BARBARA HERREN, RACHEL BEZNER KERR, EDMUNDO BARRIOS, ANDRÉ LUIZ GONÇALVES, FERGUS SINCLAIR, 2020 - Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. Agronomy for Sustainable Development, Volume (40)
23.YANG S-R, CHEN X-R, HUANG H-X, YEH H-F., 2024 - Innovation in Water Management: Designing a Recyclable Water Resource System with Permeable Pavement. Water, 16(15):2109
24.YOGESH K. DWIVEDI, LAURIE HUGHES, ARPAN KUMAR KAR, ABDULLAH M. BAABDULLAH, PURVA GROVER, ROBA ABBAS, DANIELA ANDREINI, ET AL., 2021 - Climate change and COP26: Are digital technologies and information management part of the problem or the solution? An editorial reflection and call to action. International Journal of Information Management, Volume (63)
25.ZHANG, H., HE, X., MA, R. (2025). Study on the Flood Season Staging of the Altash Water Control Project in Xinjiang. Sustainability, 17(6), 2716