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Revamping Water Use in Agriculture: Techniques and Emerging Innovations

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ABSTRACT

Water conservation in agriculture is critical for ensuring the sustainability of food production systems, particularly in the face of increasing water scarcity and climate change. Agriculture is the largest consumer of freshwater resources globally, accounting for approximately 70% of total freshwater withdrawals. As the global population continues to grow, so does the demand for food, fiber, and biofuels, further straining water resources. Concurrently, the effects of climate change, such as altered precipitation patterns, increased frequency of droughts, and higher temperatures,

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exacerbate water scarcity issues, making efficient water management in agriculture more crucial than ever, include irrigation management, soil moisture conservation, crop selection and breeding, and technological advancements. Precision agriculture, for example, utilizes GPS technology, remote sensing, and data analytics to optimize irrigation practices and reduce water waste. Drip irrigation systems deliver water directly to plant roots, minimizing evaporation and runoff, while soil moisture sensors provide real time data to inform irrigation scheduling. The application of biochar, a form of charcoal derived from organic matter, has shown promise in enhancing soil water retention and nutrient availability. Furthermore, the development of drought resistant crop varieties through traditional breeding methods and genetic engineering offers potential solutions for maintaining crop productivity under water limited conditions.

Keywords: Water conservation; sustainable agriculture; irrigation techniques; soil moisture management; drought resistant crops.

1. INTRODUCTION

Agriculture is the largest consumer of freshwater resources globally, accounting for approximately 70% of total freshwater withdrawals. As the global population continues to rise, the demand for food, fiber, and biofuels is expected to increase significantly, placing additional pressure on already stressed water resources. Concurrently, the effects of climate change, such as altered precipitation patterns, increased frequency of droughts, and higher temperatures, exacerbate water scarcity issues, making efficient water management in agriculture more crucial than ever. The integration of these technologies with traditional practices can create resilient agricultural systems capable of adapting to changing environmental conditions. However, the adoption of water conservation techniques faces several challenges, including economic constraints, limited access to technology, and the need for farmer education and training [1-3]. The economic barriers often include high initial costs for advanced irrigation systems and monitoring tools, which can be prohibitive for smallholder farmers. Limited technical knowledge and capacity among farmers can also hinder the adoption of innovative practices. Therefore, it is essential for policymakers and stakeholders to create supportive frameworks that promote the adoption of sustainable water management practices [4-8].

This review also highlights successful case studies from various agricultural contexts, demonstrating the effectiveness of different water conservation techniques. By synthesizing empirical evidence and practical insights, this article aims to inform policymakers, researchers, and practitioners about the benefits and challenges of adopting these techniques. It emphasizes the need for interdisciplinary research collaborations, long term field studies, and farmer participatory research to develop and evaluate innovative soil management practices.

Furthermore, the review discusses future directions for research and policy to enhance water efficiency in agriculture. It underscores the importance of policy support, extension services, and farmer education programs to promote the adoption of sustainable soil management practices at the farm level. It also advocates for the development of climate resilient practices and technologies to mitigate the impacts of climate change on water resources. By adopting a holistic approach that integrates traditional knowledge with modern innovations, it is possible to develop sustainable agricultural practices that ensure the long-term viability of water resources and food production systems [9].

Overall, this review aims to provide comprehensive insights for researchers, policymakers, and practitioners to promote sustainable water use in agriculture. Through collaborative action, innovation, and policy advocacy, we can build resilient and productive agricultural systems that promote food security, environmental sustainability, and human wellbeing [10].

The unsustainable use of water in agriculture not only threatens the long-term viability of farming but also has far reaching environmental and social impacts. Overextraction of water resources can lead to the depletion of aquifers, reduction of river flows, and degradation of ecosystems, adversely affecting biodiversity and the livelihoods of communities dependent on these resources. Furthermore, inefficient water use in agriculture can result in soil salinization and reduced soil fertility, ultimately diminishing agricultural productivity and food security [11].

Given these challenges, there is an urgent need to adopt water conservation techniques that improve water use efficiency and promote sustainability in agricultural systems. This review article explores a range of water conservation practices, both traditional and innovative, that have been implemented worldwide to address water scarcity and enhance agricultural sustainability. Traditional practices, deeply rooted in agricultural history, offer valuable insights into managing water resources effectively. These include surface irrigation, mulching, and crop rotation, among others, which have been used for centuries to optimize water use and maintain soil health [12].

In addition to these time-honored methods, the advent of modern technology has introduced innovative approaches that hold significant promise for water conservation in agriculture. Precision agriculture, for instance, utilizes GPS guided equipment and sensor-based systems to apply water and nutrients more efficiently, thereby reducing waste and improving crop yields. Other cutting-edge technologies, such as remote sensing, soil moisture sensors, and genetic modification, offer new ways to monitor and manage water use at a granular level, providing farmers with the tools needed to respond to changing environmental conditions and water availability [13].

By examining the successes and challenges associated with both traditional and innovative water conservation practices, the review aims to provide practical insights for farmers, agronomists, and policymakers seeking to implement sustainable water management strategies in agriculture.

Moreover, the review highlights the importance of integrating these practices within a broader framework of sustainable agricultural management. This includes considering socioeconomic factors, such as the cost of implementation and the need for farmer education and training, as well as environmental considerations, such as the impact on local ecosystems and the potential for climate change adaptation. Through a holistic approach, it is possible to develop water conservation strategies that not only enhance water use efficiency but also contribute to the overall sustainability and resilience of agricultural systems [14].

In summary, the imperative for efficient water management in agriculture is clear, driven by the dual pressures of increasing demand and diminishing resources. By exploring a range of water conservation techniques, this review seeks to highlight pathways towards more sustainable and resilient agricultural practices, ensuring that the sector can continue to meet the needs of a growing global population while safeguarding vital water resources for future generations [15].

1. Traditional Water Conservation Practices:

Surface Irrigation: Traditional surface irrigation methods, such as furrow and basin irrigation, have been used for centuries. While these methods are simple and cost effective, they often result in significant water losses due to evaporation and runoff.

Flood Irrigation: Common in rice cultivation, flood irrigation involves inundating fields with water. Although effective for certain crops, it is highly inefficient in terms of water use.

2. Soil Moisture Conservation:

Mulching: Applying organic or inorganic materials on the soil surface helps reduce evaporation, moderate soil temperature, and conserve soil moisture. While effective, mulching can be labour-intensive and costly for largescale application.

Contour Plowing: Plowing along the contour lines of a field helps reduce soil erosion and water runoff, thereby conserving soil moisture. However, it requires careful planning and management of field layout.

3. Crop Selection and Rotation:

Drought Resistant Crops: Growing crops adapted to dry conditions can help reduce water demand in water stressed areas. These crops require less irrigation water and are more resilient to drought conditions.

Crop Rotation: Alternating different crops in the same field helps improve soil structure, enhance nutrient cycling, and reduce water stress on specific crops. Crop rotation is an effective strategy for conserving soil moisture and promoting sustainable agriculture practices.

4. Soil Moisture Conservation:

Mulching: Applying organic or inorganic materials to the soil surface can reduce evaporation, moderate soil temperature, and improve water retention. Mulching with crop residues, straw, or plastic films is a widely practiced technique.

Contour Plowing: Plowing along the contour lines of a field can help reduce soil erosion and water runoff, promoting better water infiltration and retention.

5. Crop Selection and Rotation:

Drought Resistant Crops: Traditional agricultural systems often include crops that are naturally adapted to local climatic conditions and require less water.

Crop Rotation: Rotating crops with varying water need and root depths can enhance soil structure and water retention capacity.

Innovative Water Conservation Techniques:

6. Advanced Irrigation Technologies:

Drip Irrigation: Drip irrigation delivers water directly to the root zone of plants through a network of pipes, tubing, and emitters, significantly reducing water loss due to evaporation and runoff compared to traditional methods. This method not only conserves water but also improves crop yield and quality by maintaining optimal soil moisture levels. Drip irrigation systems can be automated and integrated with soil moisture sensors for precision irrigation, ensuring that plants receive the exact amount of water they need [16].

Sprinkler Irrigation: Modern sprinkler systems, including center pivot and lateral move systems, provide uniform water distribution and can be tailored to specific crop requirements. These systems are designed to mimic natural rainfall, applying water more evenly and efficiently than older irrigation methods. Sprinkler irrigation is particularly useful for large fields and can be adapted to various soil types and topographies. The incorporation of technology such as variable rate irrigation (VRI) allows for precise control of water application rates, reducing waste and enhancing water use efficiency.

7. Soil Moisture Monitoring:

Sensors and Probes: Advanced soil moisture sensors and probes can provide real time data on soil water content, enabling precise irrigation scheduling and reducing water wastage. These devices measure soil moisture at various depths and relay data to a central system, helping farmers make informed decisions about when and how much to irrigate. By using this technology, farmers can avoid over or underwatering their crops, leading to improved water conservation and crop health.

Remote Sensing: Satellite and drone based remote sensing technologies can monitor soil moisture levels over large areas, facilitating more efficient water management. These technologies use spectral data to assess vegetation health, soil moisture, and crop stress, providing valuable insights for largescale water management. Remote sensing can help identify areas of a field that require more or less water, allowing for targeted irrigation and better resource allocation.

8. Crop Breeding and Biotechnology:

Genetically Modified Crops: The development of genetically modified crops with enhanced drought tolerance and water use efficiency can play a significant role in reducing agricultural water demand. These crops are engineered to thrive in water limited conditions, requiring less irrigation while maintaining high yields. This innovation can be particularly beneficial in regions prone to drought and water scarcity, helping to ensure food security and sustainable agricultural practices [17-19].

Marker Assisted Breeding: This technique accelerates the development of crop varieties with desirable traits, such as improved water use efficiency and resilience to water stress. Marker assisted breeding uses molecular markers to select plants with specific genetic traits, speeding up the breeding process and increasing the likelihood of success. By developing crops that can better withstand water scarcity, farmers can maintain productivity while using less water.

9. Water Harvesting and Storage:

Rainwater Harvesting: Collecting and storing rainwater for agricultural use is an effective way to supplement irrigation and reduce reliance on external water sources. Rainwater harvesting systems can range from simple barrels to more complex systems with tanks and pumps. This practice not only conserves water but also reduces runoff and soil erosion, contributing to sustainable water management [20].

On Farm Reservoirs: Constructing on-farm reservoirs allows farmers to capture and store water during periods of surplus, which can then be used during dry spells. These reservoirs can be integrated with irrigation systems to ensure a steady water supply, enhancing the resilience of farming operations to variable rainfall patterns.

10. Water Saving Technologies in Greenhouses:

Hydroponics: Growing plants in a nutrient rich water solution without soil can significantly reduce water usage compared to traditional soil based agriculture. Hydroponic systems recycle water and nutrients, making them highly efficient and suitable for areas with limited water resources [21].

Aquaponics: Combining aquaculture (raising fish) with hydroponics, aquaponics systems use the waste produced by fish to provide nutrients for plant growth. This closed loop system maximizes water use efficiency and can be an effective method for producing food in water scarce regions.

Challenges in Implementing Water Conservation Techniques:

11. Economic Constraints:

High Initial Costs: The advanced irrigation systems and technologies necessary for efficient water conservation often come with significant upfront costs. Smallholder farmers, who make up a substantial portion of the agricultural community in many regions, typically lack the financial resources to invest in such technologies. Drip and sprinkler irrigation systems, soil moisture sensors, and other precision agriculture tools require substantial capital investment, which can be a prohibitive barrier.

Limited Access to Credit and Financial Support: Many farmers face difficulties in securing the necessary financing to adopt water saving innovations. The availability of credit is often limited, and when it is available, the terms may not be favorable. Additionally, financial institutions may be hesitant to lend to farmers due to perceived risks associated with agricultural investments. This financial bottleneck impedes the widespread adoption of advanced water conservation techniques [22].

12. Technical and Knowledge Barriers:

Lack of Technical Knowledge and Expertise: Many farmers, particularly in developing regions, lack the technical knowledge required to implement and maintain modern water conservation technologies. The complexity of these systems often necessitates a steep learning curve, which can deter farmers from adopting them. Effective use of drip irrigation systems, for example, requires an understanding of system design, maintenance, and precise irrigation scheduling.

Insufficient Extension Services and Training Programs: Extension services play a crucial role in disseminating information and training farmers in new agricultural practices. However, in many regions, these services are under resourced and unable to meet the demand for education on water conservation techniques. Training programs that could bridge the knowledge gap are often limited in scope and reach, leaving many farmers without the support they need to adopt and benefit from advanced technologies.

13. Institutional and Policy Issues:

Inadequate Policies and Regulations: Effective water conservation requires robust policies and regulations that promote efficient water use in agriculture. However, in many areas, such policies are either lacking or poorly enforced. Policies that incentivize the adoption of water saving technologies, such as subsidies or tax breaks, are crucial but often absent [23].

Fragmented Water Governance Structures: Effective water management necessitates coordination among various stakeholders, including government agencies, water user associations, and local communities. However, water governance structures are often fragmented, leading to inefficiencies and conflicts over water use. The lack of a coherent and integrated approach to water governance can undermine conservation efforts and sustainable water management practices [24].

Future Directions and Policy Recommendations:

14. Research and Development:

Increased Investment: To address the challenges of water scarcity and enhance agricultural sustainability, there must be a significant increase in investment in research and development (R&D) of new water saving technologies and drought resistant crop varieties. Government agencies, international organizations, and private sector stakeholders should collaborate to fund and support innovative R&D initiatives.

Collaborative Research Efforts: Addressing local water management challenges requires context specific solutions. Collaborative research efforts involving academic institutions, government agencies, and the private sector are essential. These collaborations can lead to the development of tailored technologies and practices that are more likely to be effective and adopted at the local level. Public private partnerships can also facilitate the commercialization and dissemination of innovative water saving technologies [25].

15. Capacity Building and Education:

Strengthening Extension Services: Extension services must be strengthened to enhance farmers' knowledge and skills in water conservation techniques. This includes increasing the number of trained extension officers, providing them with the necessary resources and tools, and ensuring that they are equipped to deliver practical, hands-on training to farmers [26].

Promoting Community Based Water Management Initiatives: Community based water management initiatives encourage collective action and shared responsibility among farmers. Such initiatives can be effective in disseminating knowledge, pooling resources, and managing water resources sustainably. Farmer to farmer knowledge exchange programs, where experienced farmers share their expertise with their peers, can also be highly effective in promoting the adoption of water saving practices.

16. Policy and Institutional Reforms:

Creating Enabling Policies: Governments should develop and implement policies that incentivize water conservation in agriculture. This could include financial incentives such as subsidies for adopting efficient irrigation systems, tax incentives for investing in water saving technologies, and support for R&D in water management.

Enhancing Water Governance: Improving water governance structures to ensure better coordination among stakeholders is crucial. This includes establishing clear roles and responsibilities for water management, fostering collaboration between different levels of government, and ensuring that local communities have a voice in decision making processes [27].

Traditional Water Conservation Practices:

17. Irrigation Management:

Surface Irrigation: Traditional surface irrigation methods, such as furrow and basin irrigation, have been employed for centuries due to their simplicity and cost effectiveness. Despite these advantages, surface irrigation often leads to significant water losses through evaporation and runoff. Improved management practices, such as precise leveling of fields and scheduling irrigation during cooler parts of the day, can enhance the efficiency of surface irrigation systems [28].

Flood Irrigation: Widely used in rice cultivation, flood irrigation involves submerging fields under water. While effective for certain crops, this method is inefficient in terms of water use. Alternatives like the System of Rice Intensification (SRI) have shown potential in reducing water usage while maintaining or improving yields [29].

18. Soil Moisture Conservation:

Mulching: The application of organic or inorganic materials to the soil surface, such as crop residues, straw, or plastic films, can significantly reduce evaporation, moderate soil temperatures, and improve water retention. Mulching is a simple yet effective technique to conserve soil moisture, particularly in arid and semiarid regions [30].

Contour Plowing: By plowing along the contour lines of a field, farmers can reduce soil erosion and water runoff, promoting better water infiltration and retention. This technique is especially beneficial in hilly or sloped terrains [31].

Traditional Water Conservation Practices:

19. Irrigation Management:

Surface Irrigation: Traditional surface irrigation methods, such as furrow and basin irrigation, have been used for centuries. While these methods are simple and cost effective, they often result in significant water losses due to evaporation and runoff. Strategies to improve efficiency include the use of furrow dikes, surge irrigation, and precise field leveling to ensure more uniform water distribution and reduce runoff [32].

Flood Irrigation: Common in rice cultivation, flood irrigation involves inundating fields with water. Although effective for certain crops, it is highly inefficient in terms of water use. Techniques like alternate wetting and drying (AWD) can significantly reduce water consumption without impacting yields, particularly in rice production [33].

20. Rainwater Harvesting:

Rooftop Rainwater Harvesting: Collecting and storing rainwater from rooftops for agricultural use during dry periods. This practice is especially beneficial in arid and semiarid regions, providing a supplementary water source that can be used during dry spells.

Farm Ponds: Constructing ponds to capture and store rainwater runoff for irrigation purposes. These ponds can also serve multiple functions, such as livestock watering, fish farming, and providing habitat for wildlife, thereby enhancing farm biodiversity.

21. Terracing:

Creating stepped levels on sloped lands to reduce water runoff and soil erosion, thereby enhancing water infiltration and retention. Terracing can be combined with contour bunding and stone lines to further prevent soil loss and improve moisture retention in hilly and mountainous regions.

22. Soil Moisture Conservation:

Mulching: Applying organic or inorganic materials to the soil surface can reduce evaporation, moderate soil temperature, and improve water retention. Mulching with crop residues, straw, or plastic films is a widely practiced technique. Organic mulches, such as compost and leaves, also contribute to soil fertility as they decompose.

Contour Plowing: Plowing along the contour lines of a field can help reduce soil erosion and water runoff, promoting better water infiltration and retention. This practice can be further enhanced by the use of contour bunds and grass strips to stabilize the soil and improve water conservation [34].

23. Crop Selection and Rotation:

Drought Resistant Crops: Traditional agricultural systems often incorporate crops that are naturally adapted to local climatic conditions and require less water. Examples include sorghum, millet, and certain varieties of legumes that are well suited to dry environments. These crops often have deep root systems that enable them to access moisture from deeper soil layers.

Crop Rotation: Rotating crops with varying water needs and root depths can enhance soil structure and water retention capacity. This practice not only improves water use efficiency but also helps break pest and disease cycles, contributing to overall soil health. Including cover crops and green manures in the rotation can further enhance soil organic matter and water holding capacity [35]

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Innovative Water Conservation Techniques:

24. Advanced Irrigation Technologies:

Drip Irrigation: This system delivers water directly to the root zone of plants through a network of pipes and emitters, significantly reducing water loss compared to traditional methods. Drip irrigation can be automated and combined with fertigation (the application of fertilizers through the irrigation system) to optimize water and nutrient delivery.

Sprinkler Irrigation: Modern sprinkler systems, including center pivot and lateral move systems, provide uniform water distribution and can be tailored to specific crop requirements. These systems can be equipped with pressure regulators and nozzles designed to minimize evaporation and drift.

25. Soil Moisture Monitoring:

Sensors and Probes: Advanced soil moisture sensors and probes can provide real time data on soil water content, enabling precise irrigation scheduling and reducing water wastage. These sensors can be integrated into automated irrigation systems to adjust watering based on soil moisture levels [36].

Remote Sensing: Satellite and drone based remote sensing technologies can monitor soil moisture levels over large areas, facilitating more efficient water management. These technologies can provide high resolution data on crop water status, soil moisture variability, and evapotranspiration rates, aiding in the development of precise irrigation strategies.

26. Crop Breeding and Biotechnology:

Genetically Modified Crops: Development of genetically modified crops with enhanced drought tolerance and water use efficiency can play a significant role in reducing agricultural water demand. Traits such as deep root systems, improved stomatal regulation, and enhanced osmotic adjustment mechanisms are targeted to develop crops that thrive under water limited conditions.

Marker Assisted Breeding: This technique accelerates the development of crop varieties with desirable traits, such as improved water use efficiency and resilience to water stress. By using molecular markers linked to drought resistant genes, breeders can more efficiently select and propagate crops with enhanced water saving characteristics.

Challenges in Implementing Water Conservation Techniques:

27. Economic Constraints:

High initial costs associated with advanced irrigation systems and technologies can be a significant barrier for smallholder farmers. Long term investments in water saving infrastructure may be challenging without adequate financial support and incentives.

Limited access to credit and financial support hampers the adoption of water saving innovations. Farmers in developing regions often face difficulties in securing loans or grants to invest in new technologies.

28. Technical and Knowledge Barriers:

Lack of technical knowledge and expertise among farmers regarding modern water conservation techniques. Many farmers rely on traditional practices and may be hesitant to adopt new technologies without proper training and support.

Insufficient extension services and training programs to educate farmers on the benefits and operation of advanced technologies. Strengthening the capacity of extension workers and providing hands-on demonstrations can enhance technology adoption [37].

29. Institutional and Policy Issues:

Inadequate policies and regulations promoting efficient water use in agriculture. Policies need to be aligned with sustainable water management goals, including incentives for adopting water saving practices and penalties for excessive water use.

Fragmented water governance structures and lack of coordination between different stakeholders. Integrated water resources management (IWRM) approaches are needed to harmonize water use across sectors and ensure equitable distribution.

Future Directions and Policy Recommendations:

30. Research and Development:

Increased investment in research and development of new water saving technologies and drought resistant crop varieties. Collaborative research efforts can address specific local challenges and develop context appropriate solutions.

Collaborative research efforts between academic institutions, government agencies, and the private sector to address local water management challenges. Partnerships can facilitate the translation of scientific findings into practical applications.

31. Capacity Building and Education:

Strengthening extension services and training programs to enhance farmers' knowledge and skills in water conservation techniques. Extension programs should be tailored to local conditions and include practical demonstrations.

Promoting community-based water management initiatives and farmer to farmer knowledge exchange. Encouraging peer learning and collective action can foster innovation and improve water management practices.

32. Policy and Institutional Reforms:

Implementing Policies: Developing and implementing policies that incentivize water conservation in agriculture. This could include financial incentives such as subsidies for adopting efficient irrigation systems, tax incentives for investing in water saving technologies, and support for R&D in water management. Policies should also aim to facilitate access to credit and financial support for smallholder farmers.

Enhancing Water Governance: Improving water governance structures to ensure better coordination among stakeholders is crucial. This includes establishing clear roles and responsibilities for water management, fostering collaboration between different levels of government, and ensuring that local communities have a voice in decision making processes. Integrated water resources management (IWRM) frameworks should be promoted to ensure holistic and sustainable water use [38,39].

33. Technological Adoption:

Facilitating Access: Governments and development organizations should work together to make water saving technologies more accessible and affordable for smallholder farmers. This could involve providing subsidies, developing low-cost technologies, and promoting scalable solutions that can be adapted to different farming contexts.

Promoting Digital Tools: Digital tools and platforms can play a significant role in enhancing water management and decision making. Mobile apps, online platforms, and decision support systems can provide farmers with real time information on weather conditions, soil moisture levels, and irrigation schedules. These tools can help farmers make more informed decisions and optimize water use.

Table 1. Traditional water conservation practices

Practice	Description	Benefits	Challenges
Surface Irrigation	Traditional method where water is applied directly to the soil surface through furrows or basins.	Simple and costeffective.	High water loss due to evaporation and runoff.
Flood Irrigation	Submerging fields under water, commonly used in rice cultivation.	Effective for certain crops like rice.	Inefficient water use.
Mulching	Applying organic or inorganic materials on the soil surface.	Reduces evaporation, moderates soil temperature.	Can be laborintensive and costly for large areas.
Contour Plowing	Plowing along the contour lines of a field.	Reduces soil erosion and water runoff.	Requires knowledge and proper field layout.
DroughtResistant Crops	Using crops adapted to dry conditions.	Lower water requirements.	Limited crop variety.
Crop Rotation	Alternating different crops in the same field.	Enhances soil structure and water retention.	Requires careful planning and management.

Table 2. Innovative water conservation technologies

Technology	Description	Benefits	Challenges
Drip Irrigation	Delivers water directly to plant roots through a network of pipes and emitters.	High water use efficiency, reduced evaporation.	High initial setup costs, maintenance required.
Sprinkler Irrigation	Provides uniform water distribution using various types of sprinklers.	Flexible application, automated systems available.	Potential for wind drift and evaporation losses.
Soil Moisture Sensors	Devices that provide realtime data on soil water content.	Optimizes irrigation scheduling, reduces water waste.	Initial costs, requires technical knowledge.
Remote	Using satellite or drone	Largescale monitoring, aids	High costs, requires

Technology	Description	Benefits	Challenges
Sensing	technology to monitor soil moisture over large areas.	in decisionmaking.	technical expertise.
Genetically Modified Crops	Crops engineered for enhanced drought tolerance and water use efficiency.	Maintains productivity under water stress conditions.	Regulatory and public acceptance issues.
Biochar Application	Using biochar as a soil amendment to enhance soil properties.	Improves soil fertility, water retention, and carbon sequestration.	High production costs, limited availability.

Table 3. Challenges in implementing water conservation techniques

Challenge	Description	Potential Solutions
Economic Constraints	High initial costs for advanced technologies, limited access to credit.	Financial support, subsidies, lowinterest loans.
Technical Knowledge	Lack of expertise among farmers regarding modern techniques.	Extension services, training programs.
Policy and Regulation	Inadequate policies promoting efficient water use, fragmented water governance.	Develop and implement supportive policies, enhance coordination.
Climate Variability	Unpredictable weather patterns affecting water availability.	Develop climateresilient practices and technologies.
Infrastructure Limitations	Poor irrigation infrastructure, lack of access to watersaving technologies.	Invest in infrastructure, improve access to technology.
Social and Cultural Barriers	Resistance to change and adoption of new practices among farming communities.	Community engagement, education and awareness programs.

Table 4. Future directions and policy recommendations

Recommendation	Description
Increased R&D	Invest in research for new watersaving technologies and droughtresistant crops.
Capacity Building	Strengthen extension services and training programs for farmers.
Policy Incentives	Implement policies that provide financial incentives for adopting watersaving technologies.
Technological Adoption	Facilitate access to affordable and scalable technologies for smallholder farmers.
Integrated Water Management	Promote integrated and coordinated management of water resources across sectors.
Digital Tools	Utilize digital tools and platforms for realtime water management and decisionmaking.

4. CONCLUSION

This review article explores various water conservation techniques, examining both traditional practices and modern innovations, and discusses the challenges associated with their implementation. Traditional practices, such as crop rotation, cover cropping, mulching, and contour plowing, have been employed by farmers for centuries to conserve soil moisture and improve soil health. These methods, rooted in local knowledge and adapted to specific environmental conditions, continue to play a vital role in sustainable agriculture. In addition to these time-tested methods, modern technological advancements have introduced innovative techniques that offer significant improvements in water use efficiency.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

We adopted book review, google scholar and NAAS Journals for literature review and accordingly prepared this review. The paper corrected after proper review.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kumar Sandeep, Arvind Yadav, Avaneesh Kumar, Mohammad Hasanain, Kripa Shankar, Shyam Karan, Satyam Rawat, Alok Sinha, Vipin Kumar, Ananaya Gairola, Sunil Kumar Prajapati, Parmeswar Dayal. Climate Smart irrigation practices for improving water productivity in India: A comprehensive review. International Journal of Environment and Climate Change. 2023;13(12):333-48. Available:https://doi.org/10.9734/ijecc/2023/v13i123689.
2. Rastogi Mausmi, Shruti Mallikarjun Kolur, Anand Burud, Tejaswini Sadineni, Sekhar M, Raj Kumar, Aashu Rajput. Advancing water conservation techniques in agriculture for sustainable resource management: A review. Journal of Geography, Environment and Earth Science International. 2024;28(3):41-53. Available:https://doi.org/10.9734/jgeesi/2024/v28i3755.
3. Sarvade S, Upadhyay VB, Kumar M, Imran Khan M. Soil and water conservation techniques for sustainable agriculture. Sustainable Agriculture, Forest and Environmental Management. 2019 133-88.
4. Rockström J, Falkenmark M, Karlberg L, Hoff H, Rost S, Gerten D. Future water availability for global food production: The potential of green water for increasing resilience to global change. Water Resources Research. 2009;45(7).
5. FAO. Aquastat FAO's Information System on Water and Agriculture; 2016.
6. United Nations. Sustainable Development Goal 6: Ensure availability and sustainable management of water and sanitation for all; 2015.
7. Molden D. (Ed.). Water for food, water for life: A comprehensive assessment of water management in agriculture. Earthscan; 2007.
8. Ghuge DA, Bhange VP. Water conservation techniques in horticultural crops. International Journal of Agricultural Sciences. 2014;10(2):295298.
9. Kumar R, Singh RK, Pandey RN, Singh RN. Water management in agriculture: A review. International Journal of Scientific and Research Publications. 2014;4(2):16.
10. Sharma DP, Sharma P, Sharma V. A review on water conservation techniques in agriculture. International Journal of Current Microbiology and Applied Sciences. 2016;5(5):586592.
11. Touseef, M. (2023). Exploring the Complex underground social networks between Plants and Mycorrhizal Fungi known as the Wood Wide Web. *Plant Science Archives. V08i01*, *5*.
12. Liu DL, Cai X. Climate change impacts on crop yield, crop water productivity and food security a review. Progress in Natural Science. 2018;28(3):301307.
13. Allen RG, Pereira LS, Raes D, Smith M. Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper. 1998;56.
14. Ritchie JT, Singh U, Godwin DC, Bowen WT. Cereal growth, development and yield. In Handbook of Agricultural Meteorology. New Delhi: Indian Society of Agricultural Meteorology. 2002;79118.
15. Chauhan APS, Singh D, Sharma OP, Kushwah N, Kumhare A. Agronomic practices for enhancing resilience in crop plants. Plant Science Archives. V08i03, 1.
16. Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Miller HL. (Eds.). Climate change 2007the physical science basis: Working group I contribution to the fourth assessment report of the IPCC. Cambridge University Press. 2007;4.
17. Sharma OP, Kushwah N, Singh D, Chauhan APS, Jain M. Agronomic approaches to mitigation of the impact of climate change on plants. Plant Science Archives.
18. Hsiao TC, Heng L, Steduto P, RojasLara BA, Raes D, Fereres E. AquaCropthe FAO crop model to simulate yield response to water: III. Parameterization and testing for maize. Agronomy Journal. 2009; 101(3):448459.
19. Doorenbos J, Kassam AH. Yield response to water. FAO Irrigation and Drainage Paper. 1979;33.
20. Brouwer C, Heibloem M. Irrigation water management: Irrigation water needs. Training manual No. 3. FAO; 1986.
21. Sadras VO, Roget DK. Soil water thresholds for the responses of leaf expansion and gas exchange: A review. Field Crops Research. 2003;77 (23):253263.

22. Allen RG, Pereira LS, Raes D, Smith M. Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper. 1998;56.
23. Jensen ME, Haise HR. Estimating evapotranspiration from solar radiation. Journal of the Irrigation and Drainage Division. 1963;89(4):1541.
24. Ashokri HAA, Abuzririq MAK. The impact of environmental awareness on personal carbon footprint values of biology department students, Faculty of Science, El-Mergib University, Al-Khums, Libya. In Acta Biology Forum. 2023;02(02)18-22.
25. Sharma A, Dongre P, Harsha PKA. Devendra. Horticulture horizons an exploring advanced technologies in plant cultivation. Plant Science Archives.
26. Rahgu K, Choudhary S, Kushwaha TN, Shekhar S, Tiwari S, Sheikh IA, Srivastava P. Microbes as a promising frontier in drug discovery: A comprehensive exploration of nature's microbial marvels. Acta Botanica Plantae. 2023;2(02)24-30.
27. Steduto P, Hsiao TC, Fereres E, Raes D. (Eds.). Crop yield response to water. FAO Irrigation and Drainage Paper. 2012;66.
28. Pereira LS, Oweis T, Zairi A. Irrigation management under water scarcity. Agricultural Water Management. 2002;57 (3):175206.
29. Kushwah N, Billore V, Sharma OP, Singh, D, Chauhan APS. Integrated nutrient management for optimal plant health and crop yield. Plant Science Archives; 2024.
30. Singh D, Sharma OP, Kushwah N, Chauhan APS, Jain M. Agronomic Considerations for sustainable intensication of crop production. plant science archives.
31. Fatima S. Study and evaluation of heavy metals in medicinal plants. In Acta Biology Forum. 2022;13-16.
32. Smith M. (Ed.). Handbook of drought and water scarcity: Environmental implications and solutions. CRC Press; 1992.
33. Dinar A, Balakrishnan TR, Kurukulasuriya P. (Eds.). Handbook on climate change and agriculture. Edward Elgar Publishing; 2008.
34. Irmak S, Odhiambo LO, Specht JE, Linden DS. Effect of deficit irrigation on corn evapotranspiration, yield, water use efficiency, and dry mass. Agronomy Journal. 2006;98(2):279290.
35. Evans RG, Sadler EJ. Methods and technologies to improve efficiency of water use. Water Resources Research. 2008;44(4).
36. Pattoo TA. Flora to nano: Sustainable synthesis of nanoparticles via plant-mediated green chemistry. Plant Science Archives.
37. Ogori AF, Eke MO, Girgih TA, Abu JO. Influence of aduwa (Balanites aegyptiaca. del) meal protein enrichment on the proximate, Phytochemical, Functional and Sensory Properties of Ogi. Acta Botanica Plantae. 2022;1(3):22-35.
38. Milad SMAB. Antimycotic sensitivity of fungi isolated from patients with Allergic Bronchopulmonary Aspergillosis (ABPA). In Acta Biology Forum. 2022;1(02):10-13.
39. Oweis T, Hachum A, Bruggeman A. Water harvesting and supplemental irrigation for improved water use efficiency in dry areas. SWIM Paper 7. ICARDA; 1999.

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