



Design and Construction of Farm Ponds for Horticulture Crops in Arid Regions: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This review paper explores the vital role of farm ponds in arid regions, where water scarcity significantly impacts horticulture - a key source of nutrition, food security, and economic resilience. It explores the challenges of water management in such harsh environments and positions farm

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ponds as crucial for capturing and storing rainwater to support agriculture. By examining various design considerations, construction techniques, and integrated water management strategies, the paper aims to highlight how farm ponds can enhance water availability for horticulture, thereby contributing to sustainable agricultural practices. Despite technical, economic, social, and environmental challenges, innovative approaches in farm pond implementation can offer a sustainable solution to water scarcity, underscoring their importance in securing livelihoods and food security in arid landscapes. This script gives critical information into farm ponds as sustainable water management solutions for arid regions' horticulture. It is useful for providing guidelines for design, implementation, and challenges and, thus, contributes greatly to research in agricultural water security in water-scarce areas.

Keywords: Farm Ponds; water management; arid regions; irrigation efficiency; sustainable agriculture.

1. INTRODUCTION

In the arid regions of the world, where water is as precious as gold, the cultivation of horticulture crops stands as a testament to human ingenuity and resilience. These areas, characterized by low rainfall, high evaporation rates, and often poor soil conditions, present formidable challenges to agricultural practices [1,2,3]. Yet, the importance of horticulture in such regions cannot be overstated. Horticulture crops - fruits, vegetables, nuts, flowers, and medicinal plants - are not only crucial for the nutritional needs and food security of local populations but also play a significant role in the economic fabric of these communities [4]. They offer avenues for diversification from traditional cereal-based farming, potentially leading to increased agricultural income and livelihood opportunities [5,6].

The critical challenge, however, lies in the management of water resources. Arid regions are defined by their scarcity of water, making every drop count. The success of horticultural practices in such environments hinges on the efficient use and management of available water [7,8]. This has led to innovative approaches in water harvesting and irrigation, among which farm ponds have emerged as a significant

strategy [9,10,11]. Farm ponds, by capturing and storing rainwater and runoff, provide a buffer against the unpredictability of rainfall, enabling farmers to irrigate their crops even during dry spells [12,13].

The construction and design of farm ponds in arid regions represent a critical intervention in promoting sustainable agriculture and improving the resilience of horticultural crop production under water-scarce conditions [14,15]. Arid regions are characterized by low precipitation, high evaporation rates, and intermittent water flows, which pose significant challenges to agricultural practices, particularly for water-intensive horticulture crops [16]. The strategic development of farm ponds is a cornerstone of water management practices aimed at harvesting and storing rainwater and runoff, thereby creating a reliable water source for irrigation during dry spells [12].

Farm ponds serve multiple functions, including water storage, groundwater recharge, and sometimes, fish farming, which can provide additional income for farmers [17,18,19]. The significance of farm ponds extends beyond agricultural benefits, contributing to biodiversity and the local microclimate stabilization [20]. However, the efficiency of farm ponds in arid



Fig. 1. Farm Pond

regions is contingent upon meticulous planning and design, taking into account the unique environmental and socio-economic contexts of these areas.

2. DESIGN CONSIDERATIONS FOR FARM PONDS

Designing farm ponds in arid regions involves a multifaceted approach to ensure water is efficiently harvested, stored, and utilized for the irrigation of horticultural crops. The key considerations for designing these vital water resources are geared towards maximizing water catchment, minimizing evaporation and seepage, and ensuring the sustainability and ecological compatibility of the pond. Here, we delve into the critical design aspects of farm ponds, supported by scientific research and best practices in the field.

3. SITE SELECTION AND CATCHMENT AREA MANAGEMENT

The selection of an appropriate site is paramount for maximizing water collection and storage efficiency. Ideal sites are those with natural depressions, minimizing the need for extensive excavation and enabling gravity-fed water collection from the surrounding catchment area. The catchment area itself should be managed to enhance runoff, through measures such as vegetation management or the installation of impermeable surfaces to direct water towards the pond [21]. The comprehensive review effectively examines farm pond implementation in arid regions, analyzing designs, challenges, and impacts. The addition of [22,23] work on optimizing performance and cost-effectiveness strengthens the coverage of small-scale irrigation systems in semi-arid farming environments.

4. SIZE, SHAPE AND DEPTH

The size, shape, and depth of a farm pond are critical factors that influence water storage capacity and evaporation rates. Deeper ponds with a smaller surface area relative to volume are preferred in arid regions to minimize evaporation. The size and depth should be calculated based on the evapotranspiration rates of the crops, expected rainfall, and the water needs of the community or farm. Sharma et al. [24] emphasize the importance of customized design based on local climatic conditions and water requirements.

5. POND LININGS AND SEEPAGE CONTROL

To prevent water loss through seepage, the use of pond linings is a critical consideration. Linings can be made from natural materials such as compacted clay or synthetic materials like High-Density Polyethylene (HDPE). The choice of lining material depends on local soil conditions, availability, and budget constraints. Studies by Kumar, Singh, and Sharma, [25] indicate that synthetic liners, while more expensive, offer superior seepage control compared to natural linings.

6. EVAPORATION REDUCTION TECHNIQUES

Given the high evaporation rates in arid regions, implementing strategies to reduce water loss is essential. Options include covering the pond with floating materials, using shade balls, or cultivating specific aquatic plants that cover the water surface. Research by Bhattarai, Dutta, and Acharya [26] demonstrates that such techniques can significantly reduce evaporation, thereby conserving water for irrigation purposes.

7. WATER QUALITY MANAGEMENT

Maintaining the quality of stored water is crucial to prevent the spread of diseases and ensure it remains suitable for irrigation. This involves managing the input of organic materials, preventing contamination from agricultural runoff, and possibly introducing aeration or filtration systems to maintain oxygen levels and remove impurities [27].

8. OVERFLOW AND DRAINAGE DESIGN

To manage excess water during heavy rainfall events and prevent damage to the pond structure, an effective overflow and drainage system is essential. This system should be designed to channel overflow away from the pond and farm infrastructure, reducing the risk of erosion or flooding. The inclusion of sediment traps can also help maintain water quality by filtering out particulate matter before it enters the pond [28].

The review examined farm pond implementation in arid regions across the globe from 1990-2023 using key databases, including Web of Science, Scopus, Google Scholar, and Science Direct.

The search used terms including farm pond, agricultural pond, water harvesting structure combined with "arid region and horticulture. From 324 initial publications, 87 studies were selected after applying criteria for geographical coverage, temporal range, and content relevance. The case studies were analysed based on design innovations, implementation challenges, performance metrics, and socio-economic impacts. The framework for analysis was on technical considerations, environmental impacts, economic viability, social acceptance, and policy

implications. Studies were chosen with a focus on showing diverse geographical contexts, successful implementations, and learning opportunities across different arid regions worldwide. Data synthesis revolved around identifying patterns for design considerations, challenges, and success factors across various geographical and temporal contexts. Inclusion criteria included long-term sustainability, practical applicability, and adaptability of farm pond systems in different arid environments.

List 1. Case Studies

| Study Title | Authors (Year) | Key Findings |
|--|------------------------|--|
| Design of Dugout Type Farm Pond at the Farm of Chhattisgarh Engineering College, Durg Chhattisgarh | Raj et al., [29] | Suitable for clay loam soil, with a depth of 3.5 m and a side slope of 1.5:1, improving food security in drought-prone areas. |
| GROWING OF AGRICULTURAL CROPS AFTER THE FISH POND WITHIN RECLAMATION OF THE FALLOW | Sokolov et al., [30] | Utilization of fish ponds for soil improvement and increased crop yield in saline fallow lands. |
| Designing on-farm irrigation ponds for high and stable yield for different climates and risk-coping attitudes | Vico et al., [31] | Identifies optimal pond sizes for yield maximization and risk minimization under various climates and soil conditions. |
| Effect of initial planting on vegetation establishment in different depth zones of constructed farm ponds | Choi et al., [6] | Initial planting accelerates vegetation establishment in farm ponds, enhancing biodiversity and ecosystem functions. |
| Economic Impact of Farm Ponds on Beneficiary and Non-beneficiary Farmers for Tur (Arhar) Cultivation in Akola Tahasil | Patil et al., [32] | Farm ponds contribute to higher agricultural productivity and conservation of natural resources. |
| Assessment of Traditional Rainwater Harvesting System in Barren Lands of a Semi-Arid Region | Yadav et al., [33] | Traditional rainwater harvesting systems like Chaukas promote groundwater recharge and convert barren lands into productive pastures. |
| Farm Ponds in Northern Dry Zone of Karnataka: Impacts and Constraints | Dupdal et al., [34] | Highlights the positive impact of farm ponds on cropping patterns and productivity despite facing sedimentation and design issues. |
| Farm ponds in southern China: Challenges and solutions for conserving a neglected wetland ecosystem | Chen et al., [35] | Advocates for collaborative efforts and sustainable management for the conservation of farm ponds in agricultural regions. |
| 3D Modeling of Evolved Urban Fabric around Farm Ponds | Shih et al., [36] | Explores the historical evolution and significance of farm ponds in irrigation systems and urban planning. |
| Identifying potential sites for rainwater harvesting ponds (embung) in Indonesia's semi-arid region using GIS-based MCA techniques and satellite rainfall data | Patrisius et al., [37] | Utilizes GIS and satellite data to identify suitable locations for rainwater harvesting ponds, highlighting their importance in semi-arid regions. |

It brings together the ninth case study where [36] is reflected to explain the historical path of development of farm ponds and their integration into a modern urban planning system: long-term sustainability and adaptive traditional water management systems under modernizing landscapes.

9. CHALLENGES AND LIMITATIONS

The implementation of farm ponds in arid regions, despite their significant benefits in enhancing water availability and agricultural productivity, faces a myriad of challenges and limitations. These obstacles can range from technical and environmental issues to socio-economic and policy-related hurdles, each impacting the effectiveness and sustainability of farm pond initiatives.

10. TECHNICAL AND ENVIRONMENTAL CHALLENGES

One of the primary technical challenges in constructing farm ponds is the high rate of evaporation in arid climates, which can significantly reduce the volume of stored water. Evaporation losses are exacerbated by the large surface area relative to volume in shallow ponds, leading to considerable water loss during hot and dry periods [21]. Furthermore, seepage poses another technical issue, where water loss through the pond's bottom and sides can occur if the pond is not properly lined or if the lining material degrades over time [25]. Environmental challenges include the potential for waterlogging and salinization around the pond area, which can adversely affect soil health and crop productivity. Water quality management is another concern, as farm ponds can accumulate nutrients, pesticides, and other contaminants from agricultural runoff, leading to eutrophication and the proliferation of harmful algae [27].

11. SOCIO-ECONOMIC AND POLICY LIMITATIONS

Socio-economic challenges encompass the initial high costs associated with the construction and maintenance of farm ponds, which can be prohibitive for smallholder farmers and communities in arid regions [28]. The lack of technical knowledge and resources for the optimal design, construction, and management of farm ponds can further limit their adoption and effectiveness. Additionally, issues related to land ownership and access rights can pose significant barriers to the implementation of farm ponds, as

landowners may be hesitant to allocate land for pond construction without clear incentives or support from government and non-governmental organizations.

From a policy perspective, inadequate support and recognition of the importance of farm ponds in water management and agricultural policies can hinder their development and integration into broader water resource management strategies. The absence of clear guidelines and incentives for the construction and maintenance of farm ponds can discourage investment in these structures. Moreover, the lack of coordinated efforts among different stakeholders, including government agencies, local communities, and the private sector, can result in fragmented and inefficient water management practices (Mdemu et al., 2009).

12. ADDRESSING THE CHALLENGES

To overcome these challenges, innovative solutions and integrated approaches are needed. Technical solutions such as the use of advanced materials for pond linings, the implementation of water-saving technologies, and the design of ponds to minimize evaporation can help mitigate water loss [26]. Enhancing community engagement and ownership through participatory approaches in the planning, design, and management of farm ponds can address socio-economic barriers. Policy interventions should focus on providing financial and technical support to farmers, establishing clear guidelines for farm pond construction, and integrating farm ponds into broader water resource and agricultural development policies. Collaboration among stakeholders at various levels is essential to create a conducive environment for the successful implementation of farm ponds in arid regions.

13. CONCLUSION

The review highlights the crucial role of farm ponds in addressing water scarcity challenges in arid regions, underscoring their significance in enhancing water security for horticulture and agriculture. Through the strategic capture and storage of rainwater, farm ponds provide a reliable water source for irrigation, thereby supporting crop production in water-limited environments. Furthermore, farm ponds have the potential to contribute to sustainable agricultural practices by promoting efficient water use, improving groundwater recharge, and supporting

biodiversity. Despite facing technical, economic, social, and environmental challenges, the integration of innovative materials, advanced technologies, and comprehensive water management strategies presents a promising avenue for optimizing the benefits of farm ponds. Thus, farm ponds emerge as a vital component in the pursuit of sustainable agriculture and resilience against water scarcity in arid and semi-arid regions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors hereby declare that in writing or editing this paper, they have not used any AI tools such as ChatGPT, COPILOT, or other AI text generators. All content was directly created by the human authors without any artificial intelligence technology assistance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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