Study on Water Balance and Reutilization of Rainwater Harvesting with Dugout Farmpond

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Abstract

Water scarcity is a significant issue in numerous developing countries. Depending on the intensity of precipitation, rainwater has the potential to serve as a source of drinking water. Furthermore, its effective management could alleviate water and food crises in some of these regions. Farm ponds are utilized to transport water from one location to another, but they suffer from various types of losses, with seepage and evaporation being particularly problematic in the irrigation farm pond network. It is essential to minimize these losses to ensure efficient performance and the effective utilization of water. Seepage and evaporation losses are the primary challenges in unlined farm ponds. The harvested water in the farm pond can be used for various purposes, including household and irrigation.

Introduction

Water is a precious and essential natural resource, vital for life, development, and the environment. It plays a crucial role in sustaining all living organisms and ecosystems. India, despite receiving ample rainfall, has regions that are prone to drought and have issues with groundwater quality. To address these challenges, it is vital to make the best use of heavy rainfall by collecting and storing water in ponds and reservoirs. This can significantly contribute to meeting the water needs of the region, particularly for irrigation purposes. Rainwater harvesting is a key practice in areas with unpredictable rainfall and groundwater problems. It involves the collection and storage of rainwater to alleviate water scarcity, enhance groundwater replenishment, and provide a dependable water source for various applications, including drinking, agriculture, and irrigation. Farm ponds, typically created by constructing small dams or embankments across waterways or through excavation, are important components of rainwater harvesting. The drainage or catchment area that feeds these farm ponds is crucial in ensuring their effectiveness in storing and managing water resources.

Evaporation and Seepage losses from the farmpond

Y.R Mahalle and G.W. Adhau (2014) Farm ponds have traditionally served as a cost-effective and efficient method for preserving water resources in agriculture, particularly in saline areas. They are essential for livestock watering and irrigation. To combat drought in Vidarbha's drought-prone districts, the construction of dug-out ponds for rainwater harvesting has been a key strategy in recent years. Research findings indicated that unlined dug-out farm ponds experienced significant evaporation and seepage losses of 58.82 and 12.60 cm, respectively, during the three-month water storage period from October to December. Lined Black polyethylene ponds, on the other hand, showed an evaporation component ranging from 19.51 to 24.60 percent of the storage period. Utilizing the harvested runoff water from these farm ponds for protective irrigation led to substantial improvements in dry land productivity. Cotton and Gram crops witnessed impressive yield increases of 47 to 55 percent and 43 to 58 percent, respectively. These results underscore the importance of farm ponds in promoting sustainable agriculture and combating water scarcity in drought-affected regions.

Claude E. Boyd (2011) Water budgets were established for four small experimental ponds in Auburn, Alabama, spanning from April 1 to October 31, 1981. During this study, water sources in centimetres for the specified period were as follows: rainfall 60.2 cm, runoff 2.3 cm, and regulated additions 8 to 283 cm. Rainfall was controlled because water levels were deliberately kept below drain pipes. Water losses in centimetres during this time frame included evaporation 7.7 cm, seepage ranging from 8.7 to 260.2 cm, and overflow between 2.6 and 10.3 cm. Seepage, which varied significantly among the ponds, emerged as the most critical factor influencing the need to add water to maintain water levels. For the entire 10.85-hectare complex of small experimental ponds, an average of 137,300 cubic meters of water per year would be necessary to maintain levels from March 1 through October 31. Additionally, 99,200 cubic meters would be required initially to fill the ponds

Ms. K.D. Uchdadiya (2014) Minimizing canal losses is crucial for efficient water usage. Seepage loss is a significant contributor, with measurement posing challenges due to large canal dimensions and continuous flow. Traditional methods like ponding and inflow-outflow are impractical for large or short reaches. Seepage meter techniques require numerous measurements. Analytical solutions oversimplify real-world scenarios. Investigating unlined and lined irrigation canals using Swamee et al.'s equations revealed seepage losses: unlined 0.415 cumec, brick-lined 0.0511 cumec, P.C.C.-lined 0.0028 cumec, and P.C.C. with LDPE film-lined 1.2×10^{-4} cumec. Lining canals led to impressive reductions in seepage losses by approximately 87.68%, 99.30%, and 99.97%, respectively.

Roshni patel and Sneha patel (2016) Canals play a crucial role in transporting water from one place to another. However, they suffer from various forms of water loss, with seepage and evaporation being significant culprits in irrigation canal networks. Reducing these losses is vital for efficient water use. Seepage losses occur beneath the canal, and various methods help measure them. Unlined canals are especially prone to seepage losses, while lining canals significantly reduces such losses. This paper focuses on analyzing seepage losses in lined canal networks, particularly at a specific canal section and for maximum discharge. It aims to address these challenges for more effective water utilization.

M.S Pendke B.W. Bhuibhar (2014) he studies, conducted at Vasantrao Naik Marathwada Krishi Vidyapeeth in Parbhani from 2010-11 to 2013-14, focused on reutilization of protective irrigation for soybeans in the 2013 kharif season. On average, 12.43% of runoff and 11.10% of rainfall were harvested from a 1.60 ha catchment area during the experimental period. The study revealed an average total storage loss of 1718.10 m3 from July to December, with 150.59 m3 (8.67%) due to evaporation and 1567.51 m3 (90.29%) due to seepage. Providing one protective irrigation of 5 cm to soybeans during a critical dry spell increased soybean grain yield by 30.87%. The farm pond had an average irrigation potential of 0.87 ha based on monthly storage volume between 2010 and 2013.

Claude E. Boyd (2011) Evaporation measurements were taken for a pond in Auburn, Alabama, which was lined to prevent seepage and equipped with a runoff-diverting barrier. The study covered one year from November 1982 to October 1983. Analysis through a chloride budget and laboratory permeability test confirmed that the pond did not seep. To estimate pond evaporation using class-A pan coefficients, the values ranged from 0.72 in March to 0.90 in September, with an average of 0.81. Alternatively, monthly pond evaporation in millimeters (Y) can be estimated using the equation: $Y = -2.755 + 0.848X$, where X represents monthly class-A pan evaporation in millimetres, and the coefficient r is 0.995. In the absence of class-A pan evaporation data, monthly pond evaporation in millimetres may be estimated from monthly mean surface water temperatures in degrees Celsius (X) using the equation: $Y = -9.940 + 5.039X$, with an r-squared value of 0.884.

Sustainable Benefits of Urban Rainwater Harvesting

Sandra Cecilia Muhirirwe (2022) The demand for rainwater harvesting is on the rise due to its role as a supplementary water source with low ongoing maintenance costs. The study used the daily water balance method to determine the ideal rainwater tank size, employing Princeton Global Forcing (PGF) data. This data was found to effectively replicate observed rainfall. The optimal tank size depends on factors like collection area, climate, and water pricing. Larger tank sizes and collection areas result in higher reliability.

Regions with more rainfall require smaller tanks for the same reliability levels. Achieving 100% reliability necessitates collection areas exceeding 500 m2 for a daily demand of 750 L. For tank sizes over 50 m3, reliability increase is minimal. For over 50% reliability, a roof area of 250 m2 and a tank size of 120 m3 or more are recommended. Installation of rainwater harvesting systems is economically viable with a payback period of under four years, especially in high-rainfall areas. This study's findings offer insights for comparing the performance of rainwater harvesting systems and their potential applications beyond domestic and irrigation purposes.

C.J. Glendenning and F.F. van Ogtrop (2012) Agricultural production in India heavily relies on groundwater, leading to its depletion. Rainwater harvesting (RWH) for groundwater recharge is considered a solution to address this issue, particularly within watershed development programs. This review examines the hydrological effects of RWH at both the local (individual structure) and watershed scales in rural areas. Notably, there's limited field evidence confirming positive local impacts, and potential negative impacts at the watershed scale are a concern. Modeling has been used to assess watershed impacts but often lacks comprehensive data. To improve understanding, new modelling tools, increased data collection, remote sensing, and advanced statistical techniques are recommended. The review suggests evaluation criteria to assess RWH's hydrological impacts in watershed development.

Dr. Mrs. Vidula A. Swami (2018) In India, where a significant population resides in rural areas, hilly regions face challenges in soil conservation due to high water velocity. Rainwater harvesting presents an effective solution, conserving soil and increasing groundwater storage. A study was conducted to develop suitable technology for soil conservation and verify groundwater storage improvement in such areas, offering a dual benefit of protecting valuable topsoil from erosion while enhancing water availability underground. In the Kaneri watershed, Kolhapur District, Maharashtra, structures like gulley plugs, farm ponds, terraces, and contour trenches were implemented in June 2011, showcasing their positive impact on water conservation and groundwater recharge. Similar measures were applied and evaluated in the KIT campus in Gokul Shirgaon to address the specific topographical and hydrological conditions of the area.

Stefania Anna Palermo (2020) Rainwater harvesting systems offer sustainable solutions for water conservation and managing surface runoff. The collected rainwater serves various purposes, such as irrigating green roofs, gardens, and toilet flushing. To optimize water usage, a multi-objective approach involving TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and the Rough Set method was employed in different case studies. TOPSIS compared algorithms and evaluated alternative performance, while the Rough Set method, a machine learning approach, optimized rainwater harvesting systems. The results from the Rough Set method yielded six essential decision rules, providing a foundation for decision-making. TOPSIS ranked various case studies accurately due to the consideration of correlated attributes, making it superior to simple ranking methods. Numerical optimization of rainwater harvesting systems advances knowledge in the field, offering a valuable tool for determining the optimal rainwater reuse, thereby conserving water and reducing surface runoff into the sewer system.

Kumar Rakesh *et al.* (2005) The study focused on India's water resources, emphasizing their significance as a crucial national asset. Despite an annual precipitation of around 4000 km3, the country faces extreme spatial and temporal rainfall variability. The paradox is evident in places like Cherrapunji, receiving the world's highest rainfall, yet suffering water scarcity in non-rainy seasons. India's rivers yield an average annual flow of 1953 km3, and replenishable groundwater resources total 432 km3. Usable surface water and groundwater annually amount to 690 km3 and 396 km3, respectively. Growing population, improved living standards, and climate change are increasing pressure, reducing per capita water availability. Floods, droughts, groundwater overexploitation, waterlogging, and pollution pose challenges. Efforts like hydrology projects aim to bridge gaps between advanced technologies and practical water management. The study advocates a holistic approach, integrating blue and green flows, virtual water transfer, and sustainable practices to meet present and future water demands.

Md. Tariqul Islam (2017) Water resources management plays a vital role in the development of farming systems. In the Chittagong Hill Tracts of Bangladesh, where agriculture relies heavily on rainfall, a study was conducted to explore the potential of monsoonal rainwater harvesting and its impact on local cropping systems. This rainwater harvesting, managed through irrigation facilities, significantly increased cropping intensity from 155% to 300%. It included gravity flow irrigation for valley land and low-lift pumping for hillslopes and hilltops, utilizing rainwater reservoirs. These methods proved more cost-effective than groundwater pumping due to lower installation and operational expenses. Extracting the same amount of water from the aquifer required substantially more energy. The improved water supply system enabled a triple cropping system in the valley and permanent horticultural practices on the hillslopes and hilltops. This approach not only increased agricultural productivity but also helped conserve soil moisture through perennial vegetation. Water productivity and benefit-cost analyses demonstrated that vegetable and fruit production were more profitable than rice cultivation with rainwater irrigation. Additionally, the reservoir had potential for integrated farming, including fish production. The study offers valuable insights for water resource managers and government officials dealing with similar challenges, aiding in the formulation of plans, policies, and strategies to address water scarcity and promote sustainable agriculture in such regions.

Shalander Kumar (2016) This study focuses on the performance of small rainwater harvesting structures (farm-ponds) in five major rainfed states of India from 2009 to 2011. The collected rainwater was used for supplemental irrigation or recharging open-wells. These structures have proven to be highly effective in enhancing rainfed farming and increasing farm income in many cases. For example, the use of farm ponds in Maharashtra resulted in significant improvements in farm productivity, cropping intensity, and income. However, in some instances, farmers viewed these structures as occupying productive land. Despite their potential, the adoption of farm ponds remained low, except in Maharashtra. A comprehensive analysis revealed that factors like technical support, customized design, farmer participation, age, existing well ownership, annual rainfall, and household assets were major determinants of the structures' performance. This study suggests various policy and institutional options for promoting farm-level rainwater harvesting for dryland agriculture across India, taking into account the lessons learned from the analysis.

J.S. Pachpute and S.D. Tumbo (2009) The sustainability of rainwater harvesting (RWH) systems plays a crucial role in improving water productivity in various biophysical and socioeconomic conditions in Sub-Saharan Africa (SSA). A study conducted in the Makanya catchment of rural Tanzania aimed to assess the sustainability of different storage-based RWH systems, including microdams, dug-out ponds, sub-surface runoff harvesting tanks, and rooftop rainwater harvesting systems. The increasing population in upstream areas of the catchment has led to the use of RWH systems to abstract water from streams and rivers. However, agricultural intensification in hilly areas has impacted water availability for downstream uses. Sustainability of RWH systems is influenced by factors like rainfall variability, runoff quality and quantity, local skills and investment capacity, labor availability, and institutional support. Understanding and promoting the sustainability of these RWH systems is vital for enhancing livelihoods in SSA and addressing water challenges in the region.

Che-Ani A.I and Shaari N (2009) This paper addresses the issue of water scarcity in Malaysia and the implementation of rainwater harvesting systems as part of the government's proposed solution to prevent future water crises. Despite Malaysia's abundant rainfall, increasing water consumption from various sectors has strained the existing water supply infrastructure. For example, Sandakan has faced water shortages since 1984, and similar challenges occurred in Peninsular Malaysia in 1998. The cost of expanding water supply infrastructure and replacing aging systems places a burden on the government. To prevent the recurrence of water crises, a proactive approach is needed. Rainwater harvesting is proposed as a suitable solution to address this issue, offering various benefits not only to users but also to the government and the environment. By implementing rainwater harvesting systems, Malaysia can work towards ensuring a more reliable and sustainable water supply for the future.

Pawar C. B and Patil S. S.(2014) India is projected to have a stable population of around 1640 million by 2050, leading to a decline in gross per capita water availability from 1820 m3/year in 2001 to approximately 1140 m3/year in 2050. This growing concern over water scarcity necessitates alternative solutions. Micro-watershed development and rooftop rainwater harvesting measures are often recommended to address water shortages in drought-prone areas of India. This article highlights the success of a rooftop rainwater harvesting program in Renavi village, Sangli District, Maharashtra, India. An assessment of the village's potential indicates that roughly 20 lakh litters of water collected from rooftops would meet the needs of a population of 1300 for at least 78 days. This estimation aligns with the United Nations standard of 20 liters of water per person per day for cooking and domestic use in India.

B. Helmreich and H. Horn (2008) Water scarcity is a pressing issue in many developing countries, and rainwater presents a potential source of drinking water, contingent on precipitation levels. Proper rainwater management has the potential to alleviate water and food crises in these regions. Rainwater harvesting (RWH) involves the collection of surface runoff during periods of rainfall, with systems designed using local skills, materials, and equipment.

The harvested rainwater can be employed for rainfed agriculture or as a water supply for households. However, rainwater may be contaminated with bacteria and hazardous chemicals, necessitating treatment before use. Methods like slow sand filtration, solar technology, and membrane technology can effectively reduce pollution, making rainwater safe for consumption.

C.A. Rama rao and K.V. Rao (2019) Enhancing productivity, profitability, and stability in rainfed agriculture is crucial for achieving inclusive growth and improving farmers' incomes. Rainwater management through dug-out farm ponds plays a significant role in this strategy, with support provided through programs like MGNREGA and watershed development. This paper analyses the impact of farm ponds in three districts: Anantapur and Chittoor in Andhra Pradesh and Adilabad in Telangana. The profitability of farm ponds was found to vary, both across districts and within each district. Notably, Adilabad, which receives higher annual rainfall, had higher profitability, with 69% of ponds generating additional income of over Rs. 20,000 per year, compared to only 8% in Anantapur, which receives less annual rainfall. The study identifies factors associated with these variations in profitability, offering valuable insights for policy implications.

Impact of Supplementary Irrigation on Yield

R. S. Patode, M. B. Nagdeve (2021) The location of a farm pond is a critical factor in its construction. Often, farmers dig ponds without considering technical aspects. At the All India Coordinated Research Project for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, site-specific farm ponds based on catchment areas were planned and demonstrated. These ponds were designed to assess storage capacity based on runoff from the catchment area. The study focused on the relationship between catchment area, storage, and command (irrigation potential). In the 2016-2017 season, a 5-hectare catchment area received 301.3 mm of runoff, resulting in the accumulation of 2014.8 m3 of water in the farm pond. This established a catchment-storage-command relationship: from a 5-hectare catchment, 2014.8 m3 of water could be stored in the farm pond, irrigating approximately 4.0 hectares of land. Additionally, the stored water was used for protective irrigation of various crops, leading to increased yields of soybeans during Kharif, chickpeas during Rabi, and vegetables during the winter and summer seasons.

Dr. Dattatray Sheshrao Ghungarde (2021) This paper investigates agricultural development through the impact of farm ponds on cropping patterns, focusing on the case of Wadule village in Ahmednagar district. Farm ponds are artificial structures designed to collect and store surface runoff water for secure irrigation. The study's primary objective is to comprehend how the introduction of farm ponds has influenced cropping patterns, productivity, and the socio-economic development of farm pond-holding farmers in Wadule village. The research combines primary and secondary data sources, and the findings reveal a substantial 53.28% increase in the Gross Cropped Area (GCA) for farm pond-holding farmers following the construction of the farm ponds. Cereal crops dominate the GCA, accounting for 51.90%, while pulses make up 30% of the GCA in Wadule village. Kharif season crop proportions decreased by 333.33% after farm pond implementation, while Rabi season crop proportions increased by 30.54%. Furthermore, the productivity of all crops saw significant improvement, attributed to the availability of protective and reliable irrigation facilitated by farm ponds. The results suggest the construction of more farm ponds in drought-prone areas to enhance agricultural productivity and sustainability.

Conclusion

1. Reducing seepage and evaporation losses in farm ponds and similar water storage systems can be achieved through various methods and maintenance practices.
2. Rainwater harvesting seems to be a beneficial method for minimizing water scarcity in developing countries

3. For agricultural use, most of the harvested water can be stored underground in natural systems, protecting it from evaporation.
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