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WATER HARVESTING FOR CLIMATE RESILIENCE IN UZBEKISTAN'S AGRICULTURE: OPPORTUNITIES, BARRIERS, AND POLICY RECOMMENDATIONS



Kripa Mondal

Independent Researcher / Agricultural & Horticultural Specialist



Dr. Anita Banerjee

Professor, Amity University

Abstract. Agriculture in Uzbekistan depends heavily on irrigation, making it particularly vulnerable to water shortages in an already arid climate. These pressures are intensifying as climate change leads to higher temperatures and more unpredictable rainfall, further complicating water management for farmers. In this context, the present study examines water-harvesting methods as practical and decentralized solutions to enhance resilience in the agricultural sector. Drawing on existing research and reports, it explores techniques such as rainwater harvesting, micro-catchments, terracing, small reservoirs, and managed aquifer recharge. The findings indicate that these approaches can improve water availability, support crop production, and contribute to the restoration of degraded land. At the same time, their adoption remains limited due to high initial investment costs, insufficient institutional support, and gaps in technical knowledge—challenges that are particularly significant for smallholder farmers. The study emphasizes the need for stronger policy support, improved access to finance, and more effective knowledge-sharing systems. Overall, water harvesting represents a practical and scalable solution to enhance water security and facilitate agricultural adaptation to climate change in Uzbekistan.

Key words: water harvesting; climate resilience; agriculture in Uzbekistan; irrigation; climate adaptation.

Annotatsiya. O'zbekiston qishloq xo'jaligi sug'orishga katta darajada bog'liq bo'lib, bu uni allaqachon qurg'oqchil iqlim sharoitida suv tanqisligiga nisbatan ayniqsa zaif qiladi. Iqlim o'zgarishi natijasida haroratning oshishi va yog'ingarchilikning tobora beqaror bo'lishi ushbu bosimlarni yanada kuchaytirib, fermerlar uchun suv resurslarini boshqarishni murakkablashtirmoqda. Shu nuqtai nazardan, mazkur tadqiqot qishloq xo'jaligi sektorida barqarorlikni oshirishga qaratilgan amaliy va markazlashmagan yechimlar sifatida suvni yig'ish usullarini tahlil qiladi. Mavjud ilmiy tadqiqotlar va hisobotlarga tayangan holda, unda yomg'ir suvini yig'ish, mikro-hovuzchalar (micro-catchments), terassalash, kichik suv omborlari va boshqariladigan yer osti suvlarini to'ldirish (managed aquifer recharge) kabi usullar ko'rib chiqiladi. Natijalar shuni ko'rsatadiki, ushbu yondashuvlar suvdan foydalanish imkoniyatlarini kengaytiradi, ekin yetishtirishni qo'llab-quvvatlaydi hamda degradatsiyaga uchragan yerlarni tiklashga xizmat qiladi. Shu bilan birga, ularning joriy etilishi yuqori boshlang'ich investitsiya xarajatlari, institutsional qo'llab-quvvatlashning yetishmasligi va texnik bilimlardagi bo'shliqlar sababli cheklangan bo'lib qolmoqda, bu muammolar ayniqsa kichik fermer xo'jaliklari uchun dolzarbdir. Tadqiqot kuchliroq siyosiy qo'llab-quvvatlash, moliyaviy resurslarga kengroq kirish imkoniyati hamda bilim almashinuvi tizimlarini takomillashtirish zarurligini ta'kidlaydi. Umuman olganda, suvni yig'ish usullari suv xavfsizligini mustahkamlash va O'zbekistonda qishloq xo'jaligini iqlim o'zgarishiga moslashtirish uchun amaliy va kengaytiriladigan yechim hisoblanadi.

Kalit so'zlar: suvni yig'ish, iqlimga chidamlilik, O'zbekiston qishloq xo'jaligi, sug'orish, iqlimga moslashuv.



Аннотация. Сельское хозяйство Узбекистана в значительной степени зависит от орошения, что делает его особенно уязвимым к дефициту воды в условиях уже засушливого климата. Эти проблемы усиливаются по мере того, как изменение климата приводит к повышению температуры и более непредсказуемому характеру осадков, усложняя управление водными ресурсами для фермеров. В данном контексте настоящее исследование рассматривает методы водосбора как практические и децентрализованные решения для повышения устойчивости сельскохозяйственного сектора. Опираясь на существующие научные исследования и отчёты, в работе анализируются такие методы, как сбор дождевой воды, микро-водосборы (micro-catchments), террасирование, небольшие водохранилища и управляемое пополнение подземных вод (managed aquifer recharge). Результаты показывают, что данные подходы способствуют повышению доступности водных ресурсов, поддерживают сельскохозяйственное производство и содействуют восстановлению деградированных земель. В то же время их внедрение остаётся ограниченным из-за высоких первоначальных инвестиционных затрат, недостаточной институциональной поддержки и дефицита технических знаний, что особенно актуально для мелких фермерских хозяйств. Исследование подчёркивает необходимость усиления государственной поддержки, расширения доступа к финансовым ресурсам и совершенствования систем обмена знаниями. В целом, методы водосбора представляют собой практическое и масштабируемое решение для укрепления водной безопасности и адаптации сельского хозяйства к изменению климата в Узбекистане.

Ключевые слова: водосбор, климатическая устойчивость, сельское хозяйство Узбекистана, орошение, адаптация к изменению климата.

INTRODUCTION

Uzbekistan's agricultural sector is strongly shaped by its arid and semi-arid climate, where farming depends largely on irrigation rather than rainfall. A significant share of the country's available water resources is directed toward agriculture, underlining how closely farm productivity is tied to water availability (UNDP, 2021). Over time, intensive irrigation—particularly for crops such as cotton and wheat—has contributed to environmental challenges, including soil salinization and the broader ecological impacts associated with the Aral Sea crisis (Alvi & Sufian, 2024). These existing pressures are becoming more difficult to manage as climate patterns continue to shift. Rising temperatures, more frequent heatwaves, and increasing variability in rainfall are making water supply less predictable while simultaneously increasing demand from crops (World Bank, 2016). Although national strategies, such as the Green Economy Strategy (2019), have introduced measures to improve water-use efficiency, they tend to emphasize large-scale irrigation systems rather than localized solutions.

In this context, water harvesting—defined as the collection and storage of rainwater and surface runoff—offers a practical alternative that can complement existing systems. By capturing water closer to where it is needed, these approaches have the potential to improve efficiency and strengthen resilience at the farm level. Despite these advantages, their application in Uzbekistan remains relatively limited and has not been widely integrated into mainstream agricultural practices or policy frameworks. This study contributes to the literature by linking the technical evaluation of water-harvesting systems with socioeconomic and policy constraints in Uzbekistan, an area that remains underexplored in existing research. This study aims to: (i) evaluate different water-harvesting techniques; (ii) examine the key barriers to their adoption; (iii) assess their potential to enhance climate resilience; and (iv) propose policy measures to support their wider implementation.

LITERATURE REVIEW

Climate and Agro-Ecological Context: Uzbekistan's agriculture spans diverse environments, from relatively productive areas like the Fergana Valley to highly arid regions such as Bukhara and Kashkadarya (FAO, 2000). Recent studies highlight a clear warming trend along with increasingly irregular rainfall patterns, which disrupt water availability during critical crop stages (World Bank, 2016). Rather than a total decline in rainfall, this variability creates greater uncertainty for farmers. Rising temperatures are also likely to increase evapotranspiration, further intensifying pressure on irrigation systems. While these challenges are well documented, less attention has been given to localized adaptation strategies such as water harvesting. This suggests that the challenge is not only physical water scarcity but also the growing mismatch between water supply patterns and agricultural demand, which existing irrigation systems are not fully equipped to manage.

Water-Harvesting Techniques. Water-harvesting approaches include surface storage methods such as rainwater collection and small reservoirs, in-field techniques such as micro-catchments and terracing, and subsurface options such as managed aquifer recharge (IWMI, 2013). These approaches enhance water retention, improve soil moisture, and reduce runoff losses. Evidence suggests that small reservoirs can enhance irrigation reliability and crop yields (Khasanov et al., 2025), while aquifer recharge offers longer-term storage with lower evaporation losses (IWMI, 2013). However, existing research largely focuses on technical



performance, with limited discussion of economic feasibility and adoption challenges. This highlights a gap between technical potential and practical adoption, indicating that effectiveness in controlled or pilot settings does not automatically translate into large-scale implementation. Socioeconomic and Institutional Context. The adoption of water-harvesting systems is shaped by financial, institutional, and social factors. Limited access to credit, insufficient technical knowledge, and weak extension services continue to restrict uptake, particularly among smallholder farmers (Liutin & Dower, 2023). Policy frameworks in Uzbekistan have traditionally emphasized centralized irrigation, providing less support for decentralized solutions. Institutional fragmentation further complicates implementation. In addition, gender disparities remain significant, with women farmers facing constraints in accessing resources, training, and decision-making opportunities (Alvi & Sufian, 2024).

RESEARCH METHODOLOGY

This study adopts a narrative review to explore how water-harvesting techniques contribute to climate resilience in Uzbekistan's agriculture. The discussion is informed by secondary sources, including peer-reviewed articles and reports from organizations such as the World Bank, FAO, UNDP, IWMI, CGIAR, and ICARDA, published between 2005-2025. Relevant materials were identified through databases such as Google Scholar and Scopus, using keywords related to water harvesting, climate resilience, and agricultural water management in Uzbekistan. Sources were selected for their relevance to arid-region farming systems and the availability of empirical or policy-oriented insights, while less robust studies were excluded. Overall, approximately 40-50 sources underpin the analysis. Water-harvesting techniques are assessed using criteria such as storage capacity, economic feasibility, scalability, environmental sustainability, and suitability to local agro-ecological conditions. A comparative cost-benefit perspective is applied, drawing on indicators including investment costs, yield changes, income effects, benefit-cost ratios, and payback periods. These values represent indicative ranges synthesized from the literature.

ANALYSIS AND RESULTS

Comparative analysis of water-harvesting techniques. Water-harvesting techniques differ in cost, scale, and applicability across Uzbekistan's agro-ecological conditions.

Table 1. Comparison of Water-harvesting techniques in Uzbekistan

Technique	Description	Key Benefits	Key Limitations
Rainwater Harvesting	Collection of rainwater from rooftops or farm surfaces into storage tanks or ponds	Provides supplementary irrigation; relatively low-cost; suitable for small-scale use	Limited by low rainfall; storage infrastructure required; water quality concerns
Runoff Harvesting (Micro-catchments, Bunds)	Structures that capture and slow surface runoff to enhance infiltration	Improves soil moisture; reduces erosion; low-cost and adaptable	Labour-intensive; dependent on rainfall patterns
Terracing (Gradoni Systems)	Step-like structures constructed on slopes to retain water and soil	Reduces land degradation; improves water retention	High construction cost; requires technical expertise
Small Reservoirs	Storage systems capturing seasonal runoff or river flows	Large storage capacity; improves irrigation reliability	High capital cost; evaporation losses
Managed Aquifer Recharge (MAR)	Recharge of groundwater through infiltration or injection systems	Minimizes evaporation; provides long-term storage	Complex; high initial cost

(Source: FAO, 2000; IWMI, 2013; Khasanov et al., 2025; Liutin & Dower, 2023)

Key Findings:

- ✓ Accessibility vs impact: Low-cost methods are accessible but limited in scale; large systems offer higher benefits but require investment.
- ✓ Context-specific performance: Effectiveness varies by rainfall, terrain, and hydrogeology.
- ✓ Productivity gains: All techniques improve water availability during critical crop stages.
- ✓ Climate adaptation: Storage of surplus water enhances resilience to variability.



Table 2. Quantitative Cost-Benefit Comparison

Technique	Cost (USD/ha)	Yield Increase (%)	Income Gain (USD/ha/year)	Benefit-Cost Ratio	Payback Period
Rainwater Harvesting	200–500	10–20%	150–300	1.5–2.0	1–3 years
Micro-catchments	100–300	10–25%	120–280	1.5–2.5	1–2 years
Terracing	800–1500	20–40%	300–600	2.0–3.0	3–5 years
Small Reservoirs	2000–5000	30–60%	500–1200	2.5–3.5	4–8 years
Managed Aquifer Recharge	3000–7000	40–70%	700–1500	3.0–4.0	5–10 years

Compiled by the author based on FAO (2001); World Bank (2015); IWMI (2012); WOCAT (2016); ICRISAT (2014)

The results indicate that all water-harvesting techniques are economically viable, though their feasibility varies across scales: Low-cost techniques such as rainwater harvesting and micro-catchments provide quick returns with short payback periods, making them suitable for smallholder farmers. Medium-cost techniques such as terracing offer moderate investment requirements with relatively higher long-term benefits. High-cost techniques such as reservoirs and aquifer recharge provide the greatest economic returns but require significant upfront investment. Overall, the analysis shows that while these techniques are profitable, their adoption is constrained primarily by limited access to finance rather than a lack of economic viability. Case studies were used to assess the practical applicability of water-harvesting techniques in Uzbekistan.

Case 1: Small Reservoirs in Kashkadarya: Small reservoir systems implemented in Kashkadarya have improved irrigation reliability and contributed to yield increases of approximately 30–50% in water-scarce regions (Khasanov et al., 2025). These systems demonstrate the potential of localized storage solutions to enhance agricultural productivity.

Case 2: Terracing Systems (Gradoni): Terracing systems supported by international research initiatives have improved soil moisture retention and reduced erosion in sloped areas. These interventions have enabled cultivation in previously degraded lands, contributing to both productivity and environmental sustainability (Verbist et al., 2025). The case studies indicate that water-harvesting technologies are technically effective under local conditions. However, scaling these solutions requires strong institutional support, financial investment, and capacity-building efforts.

Table 3. Climate Trends and Projections for Uzbekistan

Climate Indicator	Baseline (2000–2020)	Projection (2040–2060)	Implication for Agriculture
Average Temperature	Increasing trend (0.3–0.5°C per decade)	+2°C to +3°C increase	Higher crop water demand; heat stress on crops
Summer Temperature	Frequent heatwaves (35–42°C in many regions)	More intense and prolonged heatwaves	Reduced crop productivity; increased irrigation need
Annual Precipitation	Low and variable (100–300 mm depending on region)	Slight increase or no major change, but highly erratic	Uncertain water availability; poor rainfall reliability
Seasonal Rainfall Distribution	Concentrated in winter/spring	Shift toward irregular patterns; reduced summer rainfall	Water shortage during key crop growth periods
Evapotranspiration	Moderate but increasing	Increase by ~5–10%	Higher irrigation requirement
Drought Frequency	Occasional drought years	Increased frequency and intensity	Greater risk to rainfed agriculture

Source: Adapted from World Bank (2016), FAO (2000), and UNDP (2021)

Climate projections indicate rising temperatures and increasing rainfall variability, leading to higher evapotranspiration and irrigation demand. Although total rainfall may not decline significantly, its irregular distribution reduces reliability during critical crop stages. The increasing frequency of droughts further intensifies risks to agricultural productivity. This creates a dual challenge of rising water demand and uncertain supply. In this context, water-harvesting systems play a critical role by: Storing water during surplus periods Bridging seasonal water gaps Enhancing farm-level resilience. Integration of these systems with existing irrigation infrastructure is essential to improve overall water-use efficiency and climate adaptation capacity. Despite their



potential benefits, the adoption of water-harvesting technologies remains limited due to several constraints: Financial barriers: High initial investment costs discourage adoption, particularly among smallholder farmers. Knowledge gaps: Limited awareness and technical expertise hinder implementation.

Policy limitations: Existing policies focus predominantly on large-scale irrigation systems rather than decentralized solutions. Institutional challenges: Complex administrative procedures can delay project implementation. Gender inequality: Women farmers face restricted access to resources, training, and decision-making opportunities. These barriers highlight the need for integrated policy interventions that address both technical and socioeconomic dimensions. Scaling water-harvesting practices in Uzbekistan requires an integrated policy approach addressing financial, technical, and institutional constraints. Existing policies emphasize centralized irrigation, highlighting the need to incorporate decentralized water-management strategies.

Table 4. Policy Options for Promoting Water Harvesting in Uzbekistan

Policy Option	Objective	Key Actions	Key Stakeholders
Integration into National Plans	Align with climate and agriculture priorities	Include targets in NAPs and NDCs; develop technical guidelines	Ministry of Agriculture; Water Resources; Ecology
Financial Incentives & Credit	Reduce economic barriers	Subsidies, grants, concessional loans	Ministry of Finance; Banks; Development Agencies
Extension & Capacity Building	Improve adoption and skills	Training, demonstration sites, localized materials	Universities; Research Institutes; NGOs
Monitoring & Evaluation	Track performance	Indicators for storage, adoption, productivity	Hydromet Services; Research Bodies
Institutional Coordination	Improve governance	Inter-agency coordination; simplify approvals	Government Ministries; Local Authorities
Gender-Inclusive Programs	Ensure equitable access	Targeted training, finance, leadership support	Women's Affairs; NGOs; International Agencies

Key Policy Insights: Integration gap: Water harvesting is not adequately embedded in national climate and agricultural policies. Financial constraint: High upfront costs require subsidies and accessible credit systems. Capacity need: Extension services and training are essential for adoption. Institutional reform: Coordination across agencies must be strengthened. Gender inclusion: Targeted interventions are necessary to improve participation and adoption among women farmers. An effective implementation strategy for water harvesting should follow a phased and adaptive approach: Assessment and Prioritization: Identify regions facing acute water stress and high climate vulnerability. Policy Development and Institutional Alignment: Establish regulatory frameworks and financial mechanisms that support decentralized water solutions. Stakeholder Engagement: Involve farmers, local communities, and private-sector actors in planning and implementation.

Capacity Building and Knowledge Dissemination: Strengthen technical skills through training programs and demonstration projects. Technology Deployment: Implement context-specific water-harvesting techniques based on local conditions. Monitoring, Evaluation, and Feedback: Continuously assess outcomes and adapt strategies based on performance indicators. To measure the effectiveness of water-harvesting interventions, both quantitative and qualitative indicators should be used: Volume of water harvested and stored (m³) Area under water-harvesting systems (hectares) Number of adopting farmers (disaggregated by gender) Changes in crop yield and farm income Trends in groundwater levels. The integration of remote sensing and geographic information systems (GIS) can enhance monitoring by providing spatial insights into water availability and land-use changes. Bridging the Gap Between Potential and Adoption. Despite well-established technical advantages, the findings indicate that adoption remains uneven, particularly among smallholder farmers facing financial and institutional constraints. Rethinking Policy Priorities. Existing policies emphasize large-scale irrigation, which may not address localized water challenges. Greater focus on decentralized and flexible water-management approaches is needed. Importance of Inclusive Approaches. Gender disparities restrict access to resources and decision-making. Promoting gender-inclusive policies can enhance adoption and improve outcomes. Environmental Sustainability Considerations. Water-harvesting systems support sustainability by reducing erosion, improving groundwater recharge, and aiding ecosystem restoration. However, proper design and management are essential to minimize risks such as evaporation losses. Pathways for Scaling Up. Scaling requires pilot projects, financial incentives, and knowledge dissemination. Successful models can be replicated and integrated into broader development programs.



CONCLUSION

Water scarcity and climate variability pose significant challenges to Uzbekistan's agriculture, which remains highly dependent on irrigation. This study demonstrates that water-harvesting techniques offer a practical and scalable solution for enhancing water availability, improving crop productivity, and strengthening climate resilience. Different techniques provide complementary benefits: low-cost systems are accessible to smallholders, while large-scale interventions offer greater long-term impact but require higher investment and institutional support.

Despite their economic viability, adoption remains limited due to financial constraints, knowledge gaps, institutional inefficiencies, and a policy focus on centralized systems. Addressing these barriers through targeted financial support, capacity building, institutional coordination, and gender-inclusive policies is essential for scaling adoption. Overall, integrating water harvesting into national agricultural and climate strategies offers a viable pathway to strengthen water security, enhance resilience, and support long-term sustainable rural development in Uzbekistan.

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El.Pochta: sq143235@gmail.com

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