Investigating Water Harvesting Interventions for Enhanced Agricultural Resilience Amidst Geopolitical and Climate Challenges in Palestine

Mutaz W. Qafisheh[1]*

[1] *The Department of Civil Engineering, College of Engineering and Technology, Palestine Polytechnic University, Hebron, Palestine.*

**Corresponding author: mutazq@ppu.edu*

Abstract—
This research examines water harvesting interventions in Palestine to improve agricultural resilience amid geopolitical and climatic adversities. The study examines three significant earth-fill dams in the West Bank—Bani Na'im, Beit Al-Roush, and Arraba precipitation harvesting sites—identified by the Palestinian Ministry of Agriculture as essential for water management. These locations are vital for improving the region's agricultural and social resilience and water supply. Examining historical aerial and satellite imagery from 2018 to 2024, hydrologically analyzing soil properties and land cover, carefully analyzing daily and monthly rainfall data from local weather stations, and developing a three-dimensional analytical framework using Geographic Information Systems (GIS) to calculate dam capacities and water storage volumes were all part of the methodology. The sites' performance varies, according to the results. Between 2019 and 2022, the Arraba precipitation harvesting site, which receives an average of 520 mm of rainfall and 120 mm of runoff, continuously demonstrated high filling percentages, frequently reaching 100% during wet seasons. Beit Al-Roush, on the other hand, consistently showed extremely low or zero filling percentages, indicating inadequate water storage. Storage conditions for Bani Na'im varied, with minimal filling at times. The Normalized Difference Vegetation Index (NDVI) analysis of the investigated sites indicated a lack of significant improvement in vegetation health or density. The results suggest that the NDVI values remained relatively stable, showing no substantial positive change across the studied areas. The study emphasizes how water harvesting, especially for Arraba, can help mitigate water shortages made worse by geopolitical constraints and climate change. The results emphasize that better water management is required to improve water security and agricultural resilience in Palestine, including preventing evaporation measures, supporting well establishment, implementing integrated irrigation systems, and conducting continuous monitoring.

I. STUDY AREA

The three distinct water harvesting locations in the West Bank that the Palestinian Ministry of Agriculture has designated as essential elements of its water management plan are the subject of this study. These sites consist of:

- Bani Na'im Earth-Fill Dam: This dam, about 8 kilometers from Bani Na'im town, receives runoff from a catchment area of around 32 square kilometers. It is located approximately 450 meters above mean sea level on average [1].

- Beit Al-Roush Earth-Fill Dam: This dam collects runoff from a 15-square-kilometer catchment area and is situated 11 km southwest of Dura and 17 km southwest of Hebron. The dam's elevation is about 435 meters above the mean sea level[1].

- Arraba precipitation harvesting site: 12 km west of Jenin City, the harvesting site is fed by a 100 square kilometers catchment area. It is at an elevation of around 230 meters above mean sea level [1].

This study analyzes three water-harvesting systems in the southern West Bank, a region facing significant water scarcity, to assess their impact on agricultural and socioeconomic resilience and water supply. The Arraba site was included explicitly due to its notable agricultural activity. These three locations represent the broader study area and were selected based on the Climate Conflict Vulnerability Index (CCVI). The CCVI, which uses global data to predict climate, conflict, and vulnerability, gave all three sites a high score of 7 out of 10 [2,3,4,5]. Figure 1 visually represents the catchment areas for the earth-fill dams at these sites in blue, with the dams marked by colored triangles.

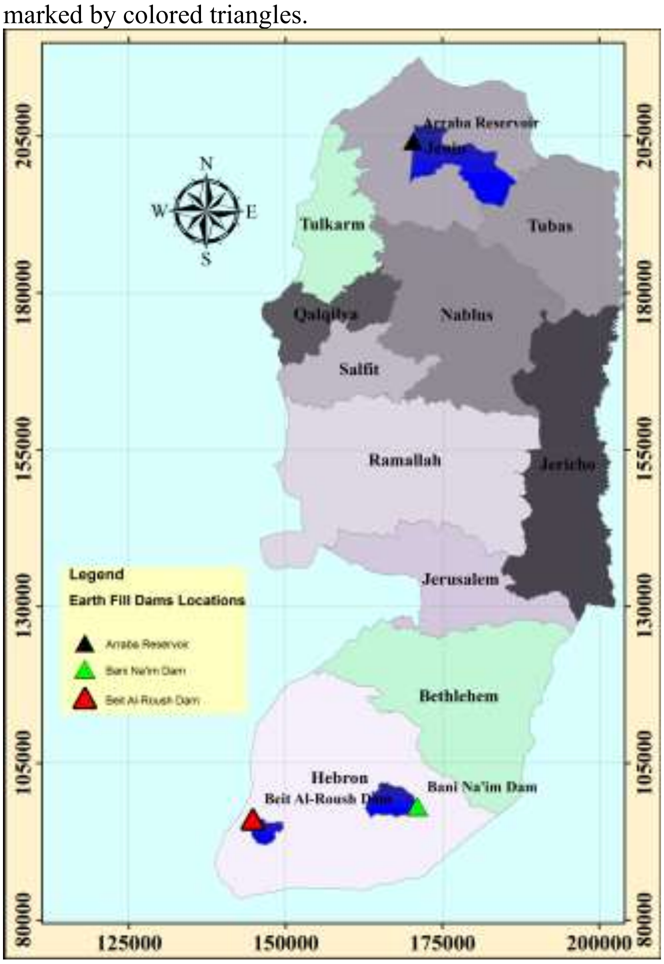


Figure 1. *West Bank Assessed Water Harvesting Locations*

Mutaz W. Qafisheh, Assistant Professor of the Department of Civil Engineering, Engineering College, Palestine Polytechnic University, Hebron, Palestine (Phone: 00972599820855; E-Mail: Mutazq@ppu.edu).

978-9950-8599-0-6

II. Introduction

The nation's development depends on the availability of water supplies. The increase in the world's population, alongside the concurrent daily living patterns, will increase the worldwide water stress. Consequently, it is anticipated that the present water demand will rise by 55 percent over the next few decades, resulting in water shortages that will impact 40 percent of the world's population [6,7,8]. Water stress is the sum of all annual water withdrawals (farming, manufacturing, and domestic) conveyed as a percentage of the total annual available blue water. The Water Resources Institute (WRI) showed in 2020 that approximately 60% of the Mediterranean countries were experiencing high levels of water stress [4,5].

❖ Water Stress in Palestine: Geopolitics, Contamination, and Supply-Demand Gaps

The country's primary natural water resources are the Jordan River and coastal and mountain groundwater; nevertheless, the Palestinians cannot utilize the Jordan River because of the geopolitical situation. Thus, they depend on water aquifers to meet their water requirements. In 2018, the World Bank Group (WBG) report stated that Palestinians are only allowed to utilize 132 million cubic meters of water per year from both coastal and mountain aquifers, and they have to acquire an extra 90 million cubic meters from Israel. It is important to emphasize that over 97% of Gaza's coastal aquifer's water does not satisfy the World Health Organization's (WHO) quality requirements [9,10,11]. The leading organizations in charge of managing water resources and irrigation in Palestinian territory are the Palestinian Water Authority (PWA) and the Palestinian Ministry of Agriculture (MoA)[12,13].

Nevertheless, both entities face difficulties meeting the Palestinian people's water requirements. In Gaza and the West Bank, over 750,000 Palestinians lack adequate access to water, according to the UN [12]. Consequently, multiple investigations reveal that Palestine's daily per capita water availability remains significantly below international recommendations. Freij, (2020) indicated a daily share of merely 88 liters per person. Furthermore, Zahra, (2001) study reported an even lower figure of approximately 55 liters per person daily. Both of these figures fall substantially short of the WHO-recommended average of 120 liters per person per day[9,14,15].

Furthermore, there are serious inefficiencies in the Palestinian water systems; in the West Bank, water loss exceeds 35% [16]. Unauthorized use and deteriorating infrastructure are the leading causes of this significant loss. As a result, this makes the current water shortage worse. A significant future difficulty for the West Bank is highlighted by projections that show the overall water supply-demand gap is expected to worsen, rising from 31.7 million cubic meters per year in 2015 to an estimated 41.2 million cubic meters per year by 2032[15].

❖ Compounding Crises: Climate Change, Aridity, and Water Insecurity in the Palestinian Territories and Mediterranean Basin

The Mediterranean basin is particularly vulnerable to climate change, experiencing significant impacts such as increased temperatures and reduced precipitation. Research consistently demonstrates that precipitation is projected to decline from 2% to 15% within this region [17,18,19]. Similarly, Palestine suffers from a severe water crisis caused by climate change, complicated geopolitical relations, and worsening natural aridity.

The emergence of challenges related to climate change increases this nation's vulnerability. Significant temperature increases are occurring in the area, with predictions pointing to an alarming rise in the following decades. When combined with less precipitation, this warming trend exacerbates water stress and increases the frequency of drought spells, endangering food security and agricultural livelihoods [20,21,22].

❖ Strategic Water Harvesting: Building Climate Resilience in Palestinian Agriculture

A comprehensive option for improving resilience and climate change adaptation is rainwater harvesting, which is centered on collecting precipitation runoff. By collecting and storing extra water, this technique is an essential tool for mitigating drought situations and preventing flash floods. Its usefulness also includes groundwater recharge, which helps to restore essential underground water supplies. The method contributes significantly to soil and water conservation by reducing erosion and raising soil moisture content. Socially speaking, water harvesting can significantly increase home water supply, especially in areas with limited water supplies, and lessen dependency on traditional sources. Additionally, it successfully lowers pollution entering natural water systems by managing surface runoff [20,21,22,23,24].

Earth-fill dams are a crucial and effective response in this challenging situation. These constructions are made to collect and hold surface runoff and rainfall, increasing the amount of water available for agricultural use, especially in places where access to conventional water sources like rivers and aquifers is limited or prohibited. The crucial lack of water storage capacities recognized as a significant barrier to the region's agricultural development is immediately addressed by constructing such dams. These initiatives seek to lessen the effects of climate-related droughts, lessen dependency on pricey purchased water, and eventually improve the resilience and sustainability of the Palestinian agricultural sector by boosting local water supplies. In this challenging context and as a response to the multifaceted water crisis, the MoA recently pursued establishing earth-fill dams and similar water harvesting structures in the West Bank. These interventions are critical to the broader strategy to enhance water security and agricultural resilience. Accordingly, the current investigation primarily focuses on assessing MoA water harvesting interventions, namely Beit Al-Roush, Bani Na'im, and Arraba precipitation harvesting site, from the construction date 2018 till 2024, which exist within a high climate conflict vulnerability index region. The findings of this study provide a foundation for subsequent investigations, particularly concerning the performance evaluation of the Al-Auja earth fill dam.

III. METHODOLOGY

The work is organized into different work packages (WP), including rainfall analysis, watershed analysis, runoff analysis, archived satellite images, aerial photos examination, and earth fill dam water storage quantity examination.

A. *Work Package 1 (Precipitation Analysis)*

The core objective of this work package was to analyze daily rainfall data obtained from local weather stations. This analysis, complemented by a detailed examination of monthly rainfall records, aimed to delineate the key characteristics of precipitation events occurring within the research area. Notably, the West Bank exhibits distinct rainfall patterns, with annual precipitation values spanning a broad spectrum: from a low of 0-100 millimeters near the Jordan Valley to a high of 700-1000 millimeters in the western mountainous terrain. The research analysis indicated that the Bani Na'im, Beit Al-Roush, and Arraba catchments receive average annual rainfall of 300mm/year, 350mm/year, and 400mm/year, respectively. Figure 2 shows the precipitation patterns in the West Bank.

B. *Work Package 2 (Hydrological Analysis)*

Several essential elements were engaged in analyzing hydrological parameters crucial for estimating runoff. Runoff generation is related to the properties of the soil, such as soil type, depth, granular structure, and texture of the soil, which directly influence infiltration rates and subsequent runoff. Similarly, the generally higher runoff from artificial surfaces than from agricultural regions indicates that land cover had a substantial secondary role in runoff regulation. Data on land cover and soil types were acquired from the portal for spatial information in Palestine GeoMolg [25].

Furthermore, according to the categorization system used by the US Geological Survey, soils were categorized into hydrological soil groups according to their infiltration rates. Lastly, Antecedent Soil Moisture (ASM), which is divided into three different classes according to moisture content, was used to measure the soil's moisture status before rainfall events. Work Package 3 then incorporated these baseline data sets to measure runoff. In particular, the Soil Conservation Service (SCS) Curve Number (CN) model. The Natural Resources Conservation Service (NRCS) established the CN empirical approach to estimate runoff volume following a precipitation event. The approach involves several analyses, including soil, land cover, and antecedent moisture condition analysis [26].

Runoff potential is closely correlated with the CN value, which ranges from 1 to 100. Higher values imply a higher possibility of runoff occurrence, whereas lower values imply less runoff. Key hydrological metrics are presented in detail at the end of this work package. The results specifically describe the average rainfall in the research area, the associated runoff volumes, and the percentage of runoff that results. The expected water production at the established earth-fill dams is then predicted using these computed parameters. It is worth highlighting that the Table 1 results were based on the investigation carried out from 2009 to 2020. The runoff percentages are varied due to the characteristics of the catchment area in terms of soil, land use, curve number, slope, and soil water content. And precipitation event pattern. Table I shows the overview results, including the average rainfall, runoff, runoff percentage, and the average amount of runoff collected from the catchment area associated with the dam locations. The work package concludes with the estimated harvested water for the selected investigation sites.

TABLE I. HYDROLOGICAL OVERVIEW RESULTS

Site	*Average Rainfall (mm)*	*Average Runoff (mm)*	*Runoff %*	*Volume (Mm^3)*
Bani Na'im	409	87	21	2.8
Beit Al-Roush	349	54	15	0.82
Arraba	520	120	23	9.8

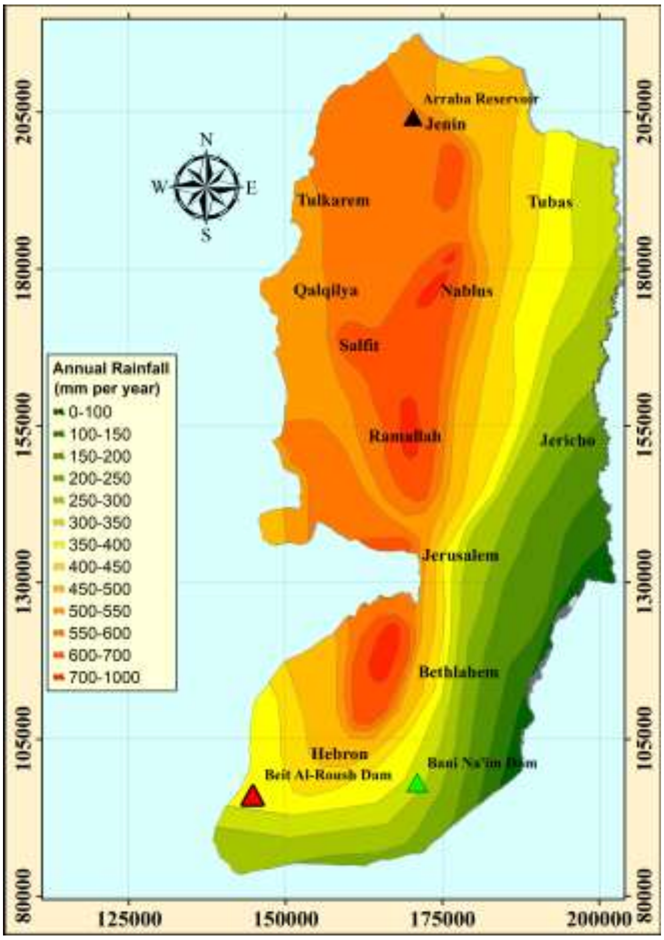


Figure 2. *West Bank Annual Precipitation Pattern.*

C. *Work Package 3 (Archived Aerial and Satellite Imagery)*

In WP 3, a thorough analysis was conducted using archived imagery from various sources, mainly Google Earth and GeoMolg. As a result, several high-resolution aerial images were downloaded, covering 2018 (the year of establishment) to 2024 (the most recent imagery). It should be noted that this effort was expanded to include both dry and wet seasons over the years stated above. The vital requirement to thoroughly investigate the earth-fill dams' storage efficiency under various climatic circumstances justifies this extension of the research's purview. Moreover, the research examines the land vegetation cover as a performance indicator of the earth-fill dam utilization efficiency. Tables II, III, and IV show the archived aerial images for the investigation sites. The third work package provides the research with a foundation to examine the selected investigation sites. It is worth highlighting that the research remark is unavailable for some table rows to have some results for some investigated years, due to the unavailability of data.

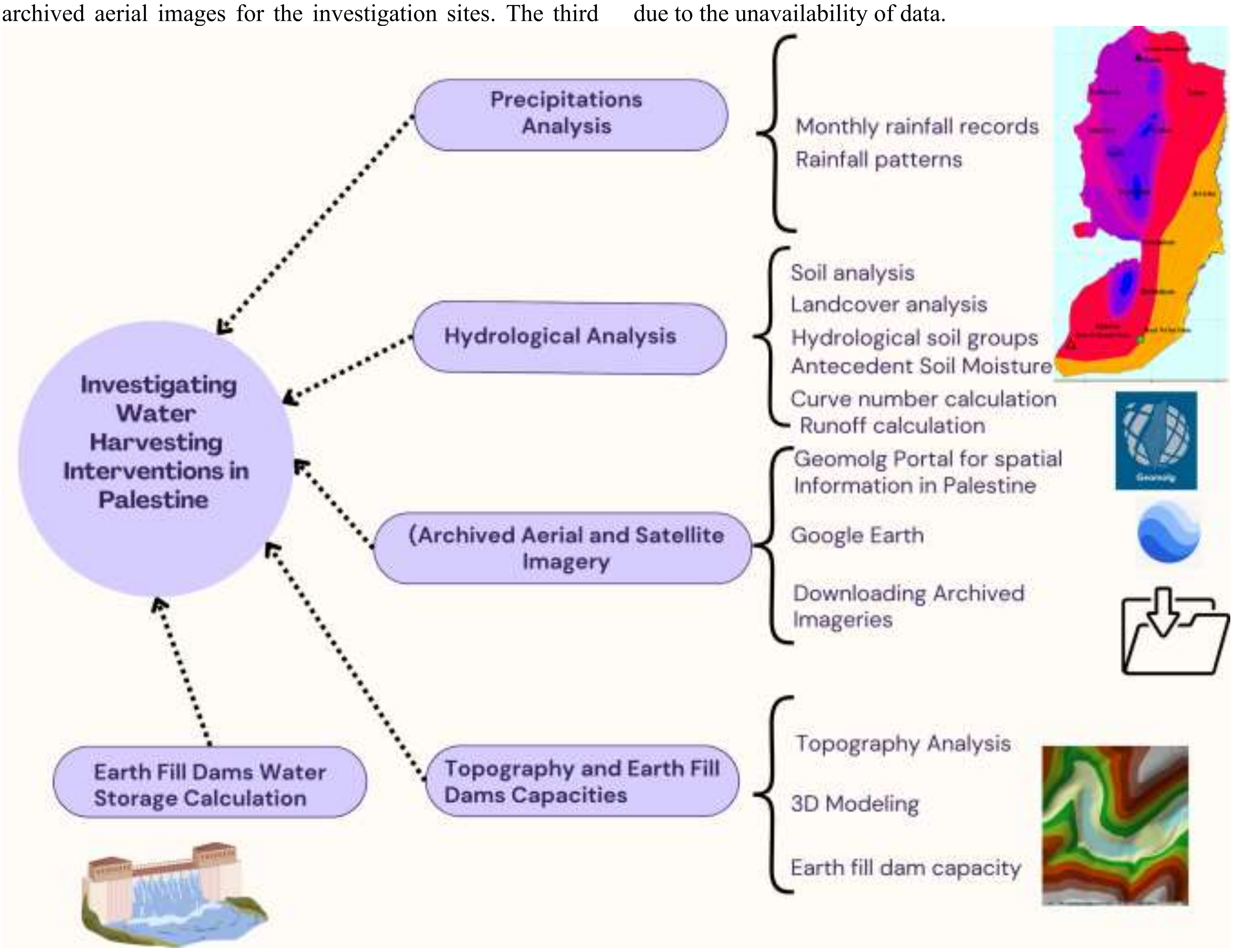


Figure 3. *Methodology Overview*

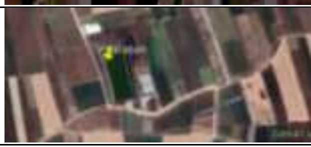
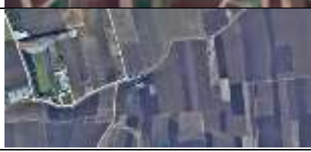
TABLE II. ARCHIVED IMAGERIES BEIT AL-ROUSH

Year	***Beit Al-Roush***
2018 dry season	
2018 wet season	Not available
2019 dry season	
2019 wet season	Not available
2020 dry season	Not available
2020 wet season	
2021 dry season	
2021 wet season	Not available
2022 dry season	Not available
2022 Wet season	
2023 dry season	Not available
2023 wet season	
2024 dry season	
2024 wet season	Not available

TABLE III. ARCHIVED IMAGERIES BANI NA'IM

Year	***Bani Na'im***
2018 dry season	
2018 wet season	
2019 dry season	
2019 wet season	Not available
2020 dry season	
2020 wet season	
2021 dry season	
2021 wet season	Not available
2022 dry season	Not available
2022 wet season	
2023 dry season	
2023 wet season	
2024 dry season	Not available
2024 wet season	

TABLE IV. ARCHIVED IMAGERIES ARRABA

Year	***Arraba***
2018 dry season	
2018 wet season	Not available
2019 dry season	
2019 wet season	Not available
2020 dry season	Not available
2020 wet season	Not available
2021 dry season	
2021 wet season	
2022 dry season	Not available
2022 wet season	
2023 dry season	
2023 wet season	
2024 dry season	Not available
2024 wet season	Not available

A. Work Package 4 (Topography and Earth Fill Dams Capacities)

Creating a three-dimensional analytical framework for the assigned investigation sites was the primary goal of WP. The required surface models were created using Geographic Information Systems (GIS). Consequently, it allows us to determine the capabilities of earth-fill dams and evaluate the water storage capacities throughout the study. Figures 4,5, and 6 show the terrain view developed with GIS for the investigation sites. The fourth work package allows the researchers to create several surface and volume analyses over the investigation years.

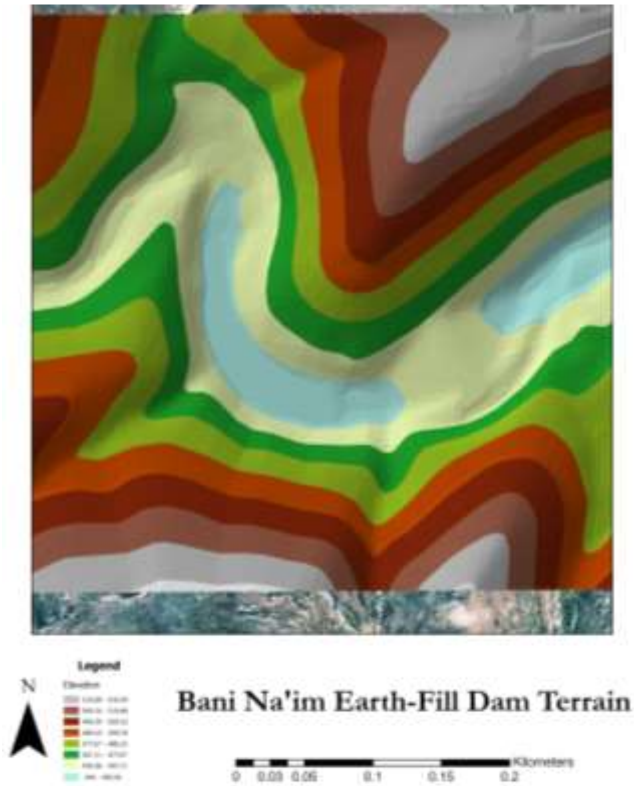


Figure 4. *Terrain view of Bani Na'im Dam*

B. Work Package 5 (Earth Fill Dams Water Storage Calculation)

Using archive images and terrain analysis data from the previous work package, Work Packages 3 and 4 were combined into Work Package 5. This integration made the computation of water storage amounts during the study period easier. Additionally, the filling percentages of earth-fill dams were calculated by comparing their maximal storage capabilities with their present storage levels, which provides an overview of the research methodology workflow.

C. Work Package 6 (Assessing Agricultural Improvements via Normalized Difference Vegetation Index (NDVI))

Remote sensing and visual imagery interpretation were employed to analyze the impact of established precipitation harvesting sites on agricultural activities. The analysis of the investigated areas revealed no significant improvements in vegetation health or density. These findings suggest that NDVI values remained relatively stable, indicating no substantial positive change across the studied sites following the implementation of precipitation harvesting. The research concluded the methodology section with Figure 3.

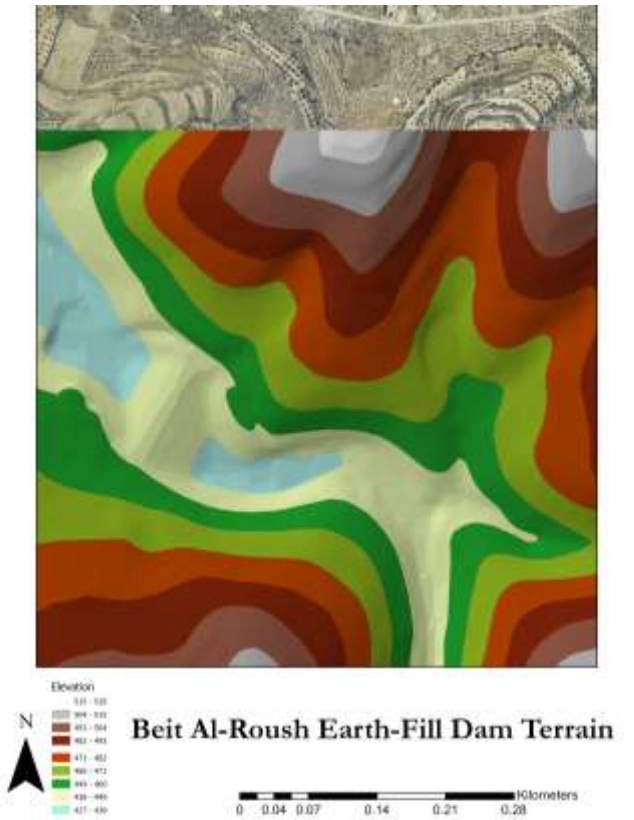


Figure 5. *Terrain view of Beit Al-Roush Dam*

Figure 6. *West Terrain View Arraba Dam*

IV. RESULTS AND DISCUSSIONS

This study conducted a hydrological review of three dam sites: Beit Al-Roush, Bani Na'im, and Arraba, analyzing their storage capacity, design parameters, and average catchment volumes. The catchment areas for each site are as follows: Beit Al-Roush at 15,092,998 m^2, Bani Na'im at 32,221,430 m^2, and Arraba at 100,728,760 m^2. These figures significantly influence each site's hydrological characteristics and water collection potential.

Arraba stands out with the most enormous catchment average volume of 9.8 Mm^3, considerably surpassing Bani Na'im's 2.8 Mm^3 and Beit Al-Roush's 0.82 Mm^3. Arraba has the highest average rainfall (520 mm) and runoff (120 mm), with a robust 23% runoff proportion. These metrics collectively indicate Arraba's superior potential for water collection among the three investigated locations.

The performance of each dam, as assessed by storage water volumes and filling percentages over several years, exhibits considerable variation.

1. Beit Al-Roush Earth Fill Dam: The capacity results for Beit Al-Roush indicate consistently low or zero filling percentages across most post-construction timeframes. The dam was under construction in 2018. Notable storage was recorded only in the 2020 wet period, with 400 m^3 (a mere 0.21% filling). Most other periods, both wet and dry, showed zero or unavailable storage, suggesting minimal effective water accumulation.

Hydrological data for Beit Al-Roush reveal fluctuating annual rainfall and runoff. Average rainfall ranged from 206 mm (2021) to 445 mm (2020), while average runoff varied from 31 mm (2021) to 67 mm (2020). Expected volumes were consistently low, mostly around 0.5 Mm^3 to 1 Mm^3.

2. Bani Na'im Earth Fill Dam: Bani Na'im displayed varied storage performance. In 2018, the dry period showed 4597 m^3 (2.51% filling) and the wet period 1020 m3 (0.5% filling). Post-2018, dry periods consistently recorded zero storage. Wet periods showed intermittent, albeit low, storage, such as 584 m^3 (0.32%) in 2020 and a more significant 5000 m^3 (2.7%) in 2024. Overall, Bani Na'im exhibited limited water storage capacity and efficiency.

The hydrological results for Bani Na'im demonstrate an average annual rainfall ranging from 224 mm (2021) to 451 mm (2020), and average runoff between 47 mm (2021) and 94 mm (2020). Expected volumes varied from 1.5 Mm^3 to 3.0 Mm^3.

3. Arraba Earth Fill Dam: Arraba consistently demonstrated substantial filling percentages, frequently achieving 100% capacity during wet seasons from 2019 to 2022 (e.g., 60,840 m^3 in 2019, 60,850 m^3 in 2021 dry period, 60,860 m^3 in 2021 wet period, and 60,830 m3 in 2022). While there was a decline to approximately 51.56% (30,945 m^3) in 2023, its performance significantly surpassed the other sites regarding water retention. The dam was under construction in 2018.

Arraba's hydrological data shows average rainfall between 239 mm (2024) and 410 mm (2023), with corresponding average runoff from 55 mm (2018, 2022, 2024) to 94 mm (2023). Expected volumes were consistently high, ranging from 5.5 Mm^3 to 9.5 Mm^3.

These results underscore significant variations in water storage efficiency and hydrological dynamics across the three sites. Arraba, with its larger catchment area and higher rainfall-runoff characteristics, demonstrates superior water collection and storage potential.

Conversely, Beit Al-Roush consistently performs poorly, and Bani Na'im exhibits limited and inconsistent storage. The investigation was somewhat constrained by the absence of archived aerial and satellite imagery, which could have provided further insights into the long-term hydrological behavior and land-use changes impacting these dam sites. Further research with comprehensive historical data would be beneficial for more robust conclusions and future water resource management strategies.

The Following Tables illustrate the main research findings.

TABLE V. BEIT AL-ROUSH EARTH FILL DAM CAPCITY RESULTS

Site	*Storage Water Volume m^3*	*Percentage of filling*
2018 dry period	Under construction	
2018 wet period	Unavailable	
2019 dry period	0	0
2019 wet period	Unavailable	
2020 dry period	Unavailable	
2020 wet period	400	0.21%
2021 dry period	0	0
2021 wet period	Unavailable	
2022 dry period	Unavailable	
2022 Wet period	0	0
2023 dry period	0	0
2023 wet period	0	0
2024 dry period	0	0
2024 wet period	Unavailable	

TABLE VI. BEIT AL-ROUSH HYDROLOGICAL RESULTS

Year	*Average Rainfall (mm)/y*	*Average Runoff (mm)*	*Expected Volume (Mm^3)*
2018	275	41	0.6
2019	339	36	0.5
2020	445	67	1
2021	206	31	0.8
2022	282	42	0.6
2023	308	46	0.7
2024	219	32	0.5

TABLE VII. BANI NA'IM EARTH FILL DAM CAPACITY RESULTS

Site	*Storage Water Volume m^3*	*Percentage of filling*
2018 dry period	4597	2.51
2018 wet period	1020	0.5
2019 dry period	0	0
2019 wet period	Unavailable	
2020 dry period	0	0
2020 wet period	584	0.32
2021 dry period	0	0
2021 wet period	Unavailable	
2022 dry period	Unavailable	
2022 Wet period	0	0
2023 dry period	0	0
2023 wet period	0	0
2024 dry period	Unavailable	
2024 wet period	5000	2.7

TABLE VIII. BANI NA'IM HYDROLOGICAL RESULTS

Year	*Average Rainfall (mm)/y*	*Average Runoff (mm)*	*Expected Volume (Mm^3)*
2018	375	78	2.5
2019	313	65	2.1
2020	451	94	3.0
2021	224	47	1.5
2022	260	54	1.8
2023	227	52	1.7
2024	300	48	1.5

TABLE IX. ARRABA EARTH FILL DAM CAPACITY RESULTS

Site	*Storage Water Volume m^3*	*Percentage of filling*
2018 dry period	Under construction	
2018 wet period	Unavailable	
2019 dry period	60840	100%
2019 wet period	Unavailable	
2020 dry period	Unavailable	
2020 wet period	44583	74.30%
2021 dry period	60850	100%
2021 wet period	60860	100%
2022 dry period	Unavailable	
2022 Wet period	60830	100%
2023 dry period	30945	51.56%
2023 wet period	30940	51.56%
2024 dry period	Unavailable	

Site	*Storage Water Volume m^3*	*Percentage of filling*
2024 wet period	Unavailable	

TABLE X. ARRABA HYDROLOGICAL RESULTS

Year	*Average Rainfall (mm)/y*	*Average Runoff (mm)*	*Expected Volume (Mm^3)*
2018	240	55	5.6
2019	318	71	7.4
2020	314	72	7.3
2021	300	69	7
2022	240	55	5.6
2023	410	94	9.5
2024	239	55	5.5

V. CONCLUSION

The research highlights the critical role of water harvesting in enhancing agricultural resilience in Palestine, particularly for the Arraba site, which demonstrated a strong capacity for water collection and storage. The study analyzed three earth-fill dams—Bani Na'im, Beit Al-Roush, and Arraba—and found significant variations in their performance. While Arraba consistently showed high filling percentages, often reaching 100% during wet seasons, Beit Al-Roush consistently had very low or zero filling percentages. Bani Na'im's storage varied with minimal filling at times.

Despite the success of the Arraba site, the Normalized Difference Vegetation Index (NDVI) analysis indicated no significant improvement in vegetation health or density across any of the sites. The findings emphasize that effective water harvesting, especially for sites like Arraba, can help mitigate water shortages exacerbated by geopolitical constraints and climate change.

VI. RECOMMENDATIONS

Earth-fill dams are a crucial and thoughtful response in this challenging situation. These constructions are made to collect and hold surface runoff after rainfall events, increasing the amount of water available for agriculture, especially in places where access to conventional water sources like rivers and aquifers is limited or prohibited. The crucial "lack of water storage capacities" recognized as an important hindrance to the region's agricultural development is immediately addressed by constructing such dams. These initiatives seek to lessen the effects of climate-related droughts, lessen dependency on pricey imported water, and eventually improve the resilience and sustainability of the Palestinian agricultural sector by boosting local water supplies. In this challenging context, the research draws the following recommendations:

- The research strongly advises the geotechnical assessment of suspected seepage, particularly at the Biet Al-Roush earth-fill dam.
- It is important to emphasize the need for evaporation prevention measures because most dry periods demonstrate that the earth-fill dam's capacity has disappeared.
- Promote Palestinian water rights and unhindered development: To guarantee that Palestinian water rights, as stipulated by international law, are upheld, the international community must apply constant pressure. Among other things, this entails calling for an end to Israeli limitations on Palestinian water development, specifically the prohibition of well drilling and dam construction, as well as the demolition and blockage of Palestinian water infrastructure and access points.
- Ensure climate-resilient water harvesting is a priority. In light of the growing climate vulnerability, increasing investment in climate-resilient water harvesting technologies, such as earth-fill dams and other runoff collection systems, is imperative. To optimize water utility, these initiatives should be combined with effective irrigation techniques, including drip irrigation, and the possibility of safely reusing wastewater should be investigated.
- Strengthen Palestinian governance and institutional capacity: encourage projects to increase the Ministry of Agriculture's and the Palestinian Water Authority's institutional capacity for managing water resources. Funding and technical support should address important internal issues like lowering network water loss, enhancing infrastructure upkeep, and implementing sustainable water use practices.
- The research highlights performing monitoring and evaluation studies thoroughly and creating frameworks for monitoring and evaluating all water harvesting infrastructure projects, including impact analyses conducted after construction. In order to inform future strategic planning and adaptation efforts, these evaluations, which should run through 2025 and beyond, should thoroughly examine project effectiveness, water availability, agricultural output, socioeconomic advantages, and the resilience of these initiatives against outside forces.

ACKNOWLEDGMENT

The author gratefully acknowledges Eng. Nidal Abu Rajab for his invaluable contributions to investigating water harvesting interventions for enhanced agricultural resilience in Palestine. His insights and dedication were instrumental in the successful completion of this research.

REFERENCES

[1] E. Efrat, *The West Bank and Gaza Strip: A geography of occupation and disengagement*. Routledge, 2006.

[2] Climate—Conflict—Vulnerability Index, "CCVI Map." Accessed: Aug. 05, 2025. [Online]. Available: https://climate-conflict.org/www/data-pages/CCVI

[3] R. J. Nicholls *et al.*, "A global analysis of subsidence, relative sea-level change and coastal flood exposure," *Nat Clim Chang*, vol. 11, no. 4, pp.

338–342, Apr. 2021, doi: 10.1038/S41558-021-00993-Z.
[4] "CCVI Methodology." Accessed: Aug. 05, 2025. [Online]. Available: https://climate-conflict.org/www/index/methodology
[5] "IPCC | Data." Accessed: Jul. 13, 2025. [Online]. Available: https://www.ipcc-data.org/
[6] R. Connor, *The United Nations world water development report 2015: water for a sustainable world*, vol. 1. UNESCO publishing, 2015.
[7] M. M. Mekonnen and A. Y. Hoekstra, "Four billion people facing severe water scarcity," *Sci Adv*, vol. 2, no. 2, p. e1500323, 2016.
[8] Y. Wada *et al.*, "Modeling global water use for the 21st century: The Water Futures and Solutions (WFaS) initiative and its approaches," *Geosci Model Dev*, vol. 9, no. 1, pp. 175–222, 2016.
[9] World Health Organization, "World Health Organization (WHO)." Accessed: Jun. 18, 2025. [Online]. Available: https://www.who.int/
[10] The UN Refugee Agency, "About UNHCR | UNHCR." Accessed: Jun. 18, 2025. [Online]. Available: https://www.unhcr.org/about-unhcr
[11] World Bank Group, "World Bank Group - International Development, Poverty and Sustainability." Accessed: Jun. 18, 2025. [Online]. Available: https://www.worldbank.org/ext/en/home
[12] Palestinian Water Authority, "PWA." Accessed: Jun. 18, 2025. [Online]. Available: https://www.pwa.ps/english.aspx
[13] Palestinian Ministry of Agriculture, "State of Palestine - Ministry of Agriculture - Official Website." Accessed: Jun. 18, 2025. [Online]. Available: https://www.moa.pna.ps/
[14] B. A. A. A. Zahra, "Water crisis in Palestine," *Desalination*, vol. 136, no. 1–3, pp. 93–99, 2001.
[15] Palestinian Central Bureau of Statistics, "PCBS | PCBS&PWA:The World Water Day on March 22nd, 2025." Accessed: Jun. 18, 2025. [Online]. Available: https://www.pcbs.gov.ps/post.aspx?lang=en&ItemID=5946
[16] D. Palestinian Water Authority, "Water Resources Data | Water Authority - State of Palestine." Accessed: Aug. 06, 2025. Available: https://www.pwa.ps/ar/Article/7155.
[17] Y. Tramblay, M. C. Llasat, C. Randin, and E. Coppola, "Climate change impacts on water resources in the Mediterranean," *Reg Environ Change*, vol. 20, no. 3, p. 83, 2020.
[18] B. Azzopardi *et al.*, "Climate and environmental change in the Mediterranean basin–current situation and risks for the future. First Mediterranean assessment report," 2020.
[19] W. Cramer *et al.*, "Climate change and interconnected risks to sustainable development in the Mediterranean," *Nat Clim Chang*, vol. 8, no. 11, pp. 972–980, 2018.
[20] J. M. Kahinda, A. E. Taigbenu, and J. R. Boroto, "Domestic rainwater harvesting to improve water supply in rural South Africa," *Physics and Chemistry of the Earth, Parts a/b/c*, vol. 32, no. 15–18, pp. 1050–1057, 2007.
[21] F. Li, S. Cook, G. T. Geballe, and W. R. Burch Jr, "Rainwater harvesting agriculture: an integrated system for water management on rainfed land in China's semiarid areas," *AMBIO: A Journal of the Human Environment*, vol. 29, no. 8, pp. 477–483, 2000.
[22] J. Rockström, "Managing water in rainfed agriculture—The need for a paradigm shift," *Agric Water Manag*, vol. 97, no. 4, pp. 543–550, 2010, doi: https://doi.org/10.1016/j.agwat.2009.09.009.
[23] M. J. Deitch and S. T. Feirer, "Cumulative impacts of residential rainwater harvesting on stormwater discharge through a peri-urban drainage network," *J Environ Manage*, vol. 243, pp. 127–136, 2019, doi: https://doi.org/10.1016/j.jenvman.2019.05.018.
[24] L. K. Singh, M. K. Jha, and V. M. Chowdary, "Multi-criteria analysis and GIS modeling for identifying prospective water harvesting and artificial recharge sites for sustainable water supply," *J Clean Prod*, vol. 142, pp. 1436–1456, 2017, doi: https://doi.org/10.1016/j.jclepro.2016.11.163.
[25] Geomolg Portal for Spatial Infromation In Palestine, "Geomolg." Accessed: Aug. 04, 2025. [Online]. Available: https://geomolg.ps/L5/index.html?viewer=A3.V1
[26] N. Natural Resources Conservation Service, "Home | Natural Resources Conservation Service." Accessed: Aug. 04, 2025. [Online]. Available: https://www.nrcs.usda.gov/