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Evaluation of Hydrogels in Improving Soil-Water Retention, Plant Survival and Climate Adaptation Strategies in Kitui County, Kenya

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ABSTRACT: Water scarcity and land degradation pose significant challenges in ASALs, exacerbating food insecurity and ecosystem vulnerability. Hence the objective of this paper was to evaluate the efficacy of hydrogels (synthetic superabsorbent polymers) in improving soil-water retention and plant survival (*M. volkensii*), aligning with SDGs 6 and 15 and climate adaptation strategies conducted in Kitui County, Kenya using appropriate standard techniques. Results demonstrated a statistically significant increase in soil moisture retention (mean difference of 2.00, $p < 0.001$) and improved seedling survival ($p < 0.05$), highlighting hydrogel's role in enhancing plant resilience under water-scarce conditions. From implication of soil-water retention improvement findings, hydrogels are noted to mitigate nutrient leaching, reduce irrigation needs, and improve soil structure to address challenges like high evapotranspiration and degraded soils. However, scalability and cost remain barriers, with bio-based hydrogels emerging as viable alternatives. This research highlights hydrogel's potential to support climate adaptation, reforestation of degraded lands, and LDN, and thus complementing global frameworks like the Kyoto Protocol and Kenya's NCCAP. Recommendations include integrating hydrogels with sustainable practices, such as agroforestry, and advancing research on cost-effective, eco-friendly formulations. Overall, this study contributes to knowledge by demonstrating hydrogels' transformative capacity for sustainable agriculture in ASALs to enable resilience against climate variability and water scarcity.

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Abbreviations: *ANOVA = Analysis of Variance; ASALs = Arid and Semi-Arid Lands; IPCC = Intergovernmental Panel on Climate Change; LDN = Land Degradation Neutrality; NCCAP = National Climate Change Action Plan; RCBD = Randomized Complete Block Design; SDGs = Sustainable Development Goals; SPSS = Statistical Package for the Social Sciences; UN = United Nations*

Water scarcity and land degradation are critical environmental challenges, particularly in Africa's arid and semi-arid lands (ASALs), which cover 43% of the continent's land area and support nearly 40% of its population (Nyuma and Churu, 2022; Okello *et al.*, 2024). Climate change has intensified these challenges by causing higher temperatures, erratic rainfall, and prolonged droughts, which have diminished agricultural productivity, accelerated desertification, and threatened biodiversity and food

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security (Abdi *et al.,* 2013). In response to these challenges, synthetic hydrogels have emerged as a promising solution (Muriithi *et al.,* 2024; Wu *et al.,* 2024). Hydrogels are highly water-absorbent materials that can retain and gradually release water, improving soil moisture retention and enhancing agricultural productivity in water-scarce regions (Tariq *et al.,* 2023; Patra *et al.,* 2022). Studies in northern Kenya and southern Ethiopia demonstrate the effectiveness of hydrogel applications in boosting plant growth and sustaining agriculture under extreme water scarcity (Kaburu *et al.,* 2021; Abdallah *et al.,* 2021). By addressing both water scarcity and land degradation, hydrogels offer a sustainable strategy for supporting livelihoods and promoting climate adaptation in ASALs (Ali *et al.,* 2024; Ashraf *et al.,* 2021).

The broader implications of hydrogel technology extend to sustainable agriculture, ecosystem restoration, and achieving global climate and development goals (Kasoju and Sunilkumar, 2024). Research shows that hydrogels improve soil-water retention, mitigate nutrient leaching, and support reforestation efforts by enhancing the survival rates of tree seedlings (such as *Melia volkensii*) in degraded lands (Dhiman *et al.,* 2022; Mudhanganyi *et al.,* 2018). Neethu *et al.* (2018) study found that hydrogel application increased water retention by up to 50%, significantly reducing the frequency of irrigation. Hydrogels also align with international objectives such as the Kyoto Protocol and SDGs, particularly SDG 6 (water management) and SDG 15 (ecosystem restoration) (Sanz *et al.,* 2017; Pandey and Kumari, 2024). Despite their potential, cost and scalability challenges limit the widespread adoption of synthetic hydrogels in ASALs, especially for smallholder farmers (Lee *et al.,* 2024). To overcome these barriers, researchers are exploring bio-based hydrogels derived from natural polymers like cellulose and chitosan, which are more affordable and eco-friendly (Wu *et al.,* 2022; Ahmadian *et al.,* 2021). In integrating hydrogel technology into national climate strategies, countries such as Kenya could enhance agricultural resilience, restore degraded lands, and support vulnerable communities, contributing to SDGs such as SDG 1 (No Poverty) and SDG 2 (Zero Hunger) (Chouhan *et al.,* 2023; Nordin *et al.,* 2024).

While from a global perspective, the role of hydrogels in achieving land degradation neutrality (LDN) is particularly noteworthy. The IPCC has highlighted the importance of LDN in building resilience to climate change and supporting sustainable development (Rackelmann *et al.,* 2024). Hydrogels contribute to LDN by promoting efficient water use, improving soil fertility, and supporting reforestation efforts, which are essential for restoring degraded lands in ASALs. Hence the objective of this paper was to evaluate the efficacy of hydrogels (synthetic superabsorbent polymers) in improving soil-water retention and plant (*Melia volkensii*) survival, aligning with SDGs 6 and 15 and climate adaptation strategies conducted in Kitui County, Kenya.

MATERIALS AND METHODS

Study Area: This research was conducted in Kitui County, Kenya, a region predominantly classified as ASAL, covering over 75% of the county. The geographical location of the county is between latitudes 0^0 10’ and 3^0 0’South and longitudes 37^0 50’ East. The area is characterized by sandy clay and porous soils with low organic matter and nutrient content, which contribute to poor water retention and limited agricultural productivity (Kambua, 2014). Rainfall is highly erratic, averaging between 201 – 500 mm annually, and is concentrated in two rainy seasons: i) long rains (between March and May, having high temperatures and a risk of flooding) and ii) short rains (between October and December, having more stable weather). The county is mostly hot and dry with temperatures ranging from 14^0 C, during the coldest months of July to August, and 34^0 C during the hottest months of January to March (Mwamati, 2017).

In addition, high evapotranspiration rates, often exceeding rainfall, exacerbate water scarcity, making Kitui an ideal location for studying innovative water retention and soil improvement solutions (Masila, 2015). The vegetation type is mainly comprised of scattered shrubs, drought-resistant grasses, acacia species, Commiphora trees, Euphorbia species, Terminalia spp., and the endangered *Melia volkensii* (Mukau). The vegetation is interspersed with exposed bare land characterized by intense soil erosion and that have left the soil leached and unable to support plant growth due to their low water and nutrient absorption and retention potential. The indigenous endemic tree species such as *M. volkensii* is at the brink of extinction due to illegal logging for timber and charcoal production (Himberg, 2006).

Study Design: This study employed an experimental study design. An experimental study involves controlled manipulation of variables to determine their effects on specific outcomes, making it a powerful tool for investigating causal relationships (Imai *et al.,* 2013). In this research, the study was designed to evaluate how hydrogel application (by quantity and mode of application) impacts critical soil and plant parameters under controlled conditions. Focusing on three key objectives, the study systematically assessed hydrogel's role in soil-water retention capacity, optimal application rates and methods, and changes in soil properties, including pH, temperature, and electrical conductivity.

Applicably, the experimental setup allowed for precise control over variables such as hydrogel concentration and application modes, and thus minimized confounding factors and enhanced the reliability of the results (Steinbeck *et al.*, 2025). This approach was particularly beneficial for identifying the best practices for hydrogel use in ASAL regions like Kitui, where water scarcity and land degradation severely impact agriculture. The findings provided actionable insights into sustainable land management strategies, especially with regard to improvement of soil health, plant survival, and long-term agricultural productivity.

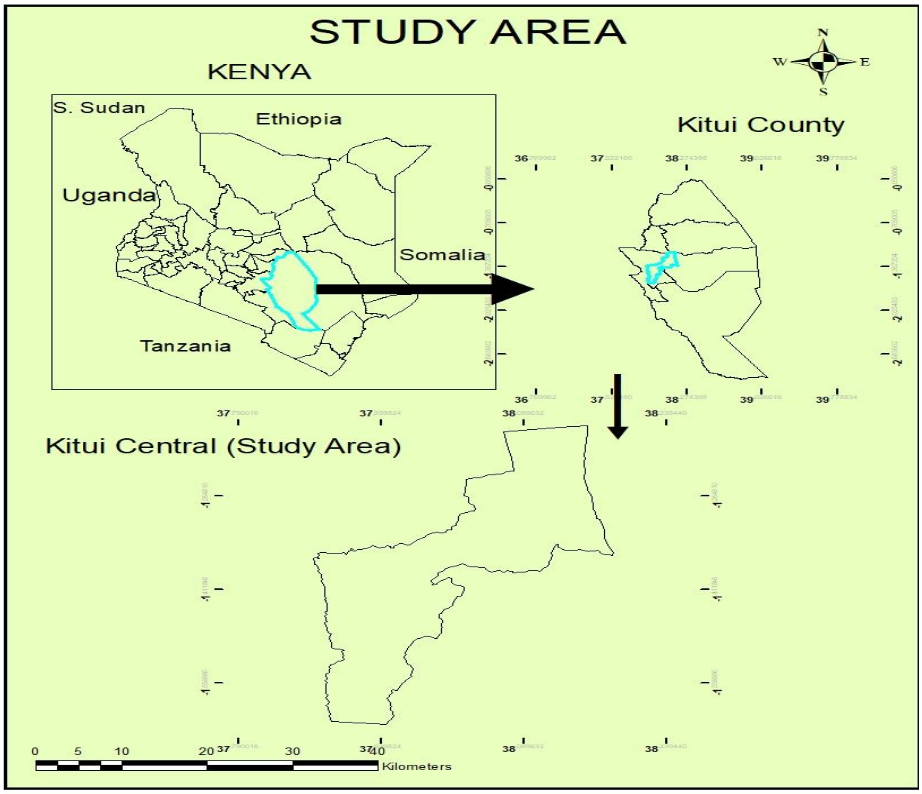

Fig. 1: The map of Kitui County, Kenya.

Table 1: Description of the quantities and modes of hydrogel application

Treatment Level	
Quantity	***Description***
0g/L	No hydrogel application (control).
1.0g/L	Low hydrogel application.
3.0g/L	Moderate hydrogel application.
6.0g/L	High hydrogel application.
Mode of Application	
Below Roots (B)	Hydrogel-soil mixture placed at the bottom of the planting pit, w from the mixture.
Within Roots (W)	Hydrogel-soil mixture directly in contact with the tips of seedling
Complete Mix (C)	Seedling roots fully surrounded by hydrogel-soil mixture.

Experimental Setup: The study employed a randomized complete block design (RCBD) with four hydrogel treatment levels (0g/L, 1.0g/L, 3.0g/L, and 6.0g/L) (Albalasmeh *et al.*, 2022) and three application modes on tree seedlings *(Melia volkensii)*: Below Roots (B), Within Roots (W), and Complete Mix (C). These combinations were replicated across multiple plots (four times) to ensure statistical reliability.

Treatments and Application Modes: Plot Layout: The experimental design included 12 plots, each representing a unique treatment and application mode combination, for example, Plot 1 (0g/L – B), Plot 2 (1g/L – W), Plot 3 (3g/L – C), etc. (Lin *et al.*, 2023). Split Plots represented variations in application modes within each treatment level. Each plot contained 10 *Melia volkensii* seedlings, resulting in 120 seedlings in total. Then, the experimental unit was defined as a single seedling, which received a specific hydrogel dose and application method. Parameters including soil moisture content and seedling survival rates were measured for each unit.

Data Collection: Soil moisture content was determined weekly (le Roux and Jacobsz, 2021), where soil samples were collected carefully to avoid disturbing seedling growth. Soil was extracted from a consistent depth near the root zone using a soil auger, with samples taken from 0–15 cm and 15–30 cm depths. The collected samples were immediately placed in airtight soil bags to prevent moisture loss. In the laboratory, the samples were weighed, oven-dried at 105°C for 24 hours, and reweighed to determine moisture content using equation 1:

$$SMC\ (\%) = \frac{Fresh\ Weight - Dry\ Weight}{Dry\ Weight} \times 100 \quad (1)$$

Where SMC = soil moisture content

Water retention characteristics were not directly measured using pF curves but inferred from soil moisture content trends over time. Planting holes were prepared with standardized dimensions of 30 cm × 30 cm × 30 cm to ensure uniform soil conditions across treatments. Moreover, seedling survival rates were assessed through weekly visual observations and health evaluations (including parameters such as height, number of leaves, and stem thickness) recording the proportion of seedlings that remained viable and exhibited healthy growth under different treatment levels and application modes. This approach ensured a robust dataset for analyzing hydrogel's efficacy in enhancing soil moisture and promoting plant survival in arid and semi-arid conditions, thereby addressing key objectives of the study effectively. Also, additional soil properties monitored included pH, electrical conductivity, and temperature. These parameters were measured biweekly using a pH meter, a conductivity meter, and a soil thermometer, respectively. This provided insights into how hydrogel application influenced soil conditions over time.

Statistical Analysis: The collected data were analyzed using statistical methods to evaluate the effects of hydrogel treatments on soil-water retention. ANOVA was employed to compare the means of soil moisture content and seedling survival rates across various treatment levels and application modes (Yan *et al.*, 2022), while the Chi-Square test assessed the associations between hydrogel application and changes in soil moisture, pH, temperature, and EC. Post-hoc tests were conducted to identify significant differences between specific treatment levels. A significance threshold of $p \leq 0.05$ was established to determine the statistical relevance of findings, ensuring robust interpretations. All analyses were conducted using SPSS (version 27) as the statistical tool to enhance accuracy and reliability of the results.

RESULTS AND DISCUSSION

Remarkable results were found when determining the how hydrogel application impacted soil-water retention capacity to improve *Melia volkensii* tree seedling survival rates. Assumption was made in this study to support that good water retention capacity is a primary highlight for climatic adaptation effective in agricultural practices. The selected treatment and mode of applications mainly featured for the evaluations of this results were of 6.0 g/L – C.

Soil-Water Retention: A One-Sample Statistics was run for the moisture content of the soil to find out how soil retained water with the application of hydrogel. The following results in the table were derived. From the table, there are 12 samples in this test. The average moisture content of the soil after hydrogel application is 2.00 cm^3/cm^3, while the Standard Deviation is 0.853. This measures the variation in moisture content across the samples. Also, the Standard Error Mean is 0.246, which represents the standard deviation of the sample mean. One-sample t-tests indicated a statistically significant increase in soil moisture content after hydrogel application (mean difference: 2.00 units, $t = 8.124$, $p < 0.001$). These findings highlight hydrogel's potential to enhance soil-water retention, a critical factor for sustainable land management in water-scarce regions. The hydrogel application (C) has a positive effect on soil moisture retention, with a mean difference of 2.00 cm^3/cm^3compared to the hypothesized value of 0 (no effect). The 95% confidence interval indicates that the true increase in moisture content is likely between 1.46 and 2.54 cm^3/cm^3. Since the result is statistically significant, it suggests that the hydrogel is effective in improving soil moisture retention for 6.0g/L level (C).

Table 2: A one-sample statistics for water-soil retention after hydrogel application

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
MC_Rep2_1.0gl	12	2.00	.853	.246

One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
MC_Rep2_1.0gl	8.124	11	.000	2.000	1.46	2.54

The One-Sample Test results provide a significant evidence of the hydrogel's effectiveness. With a test value of 0, indicating no effect, the t-value of 8.124 and the p-value of 0.000 demonstrate a strong statistical significance, confirming that the observed increase in moisture content is not due to random variation. The mean difference of 2.00 confirms that the hydrogel had a positive impact on soil moisture retention. Furthermore, the 95% confidence interval for the difference in moisture content (ranging from 1.46 to 2.54) indicates that, with 95% certainty, the true effect of hydrogel application lies within this range. This strengthens the conclusion that the hydrogel significantly enhances soil's ability to retain moisture, which could have important implications for agricultural practices (a finding that is similar to that of Patra *et al.*, 2022), especially in water-scarce regions or during drought conditions. The results strongly support the hypothesis that hydrogel application improves soil moisture retention. The statistical analysis confirms the significance of this effect, with high confidence in the observed increase in moisture content. Therefore, the results of this study align with existing literature on the role of hydrogel in enhancing soil-water retention, which is a critical component in climate adaptation strategies as also covered by Saha *et al.* (2020). Hydrogels are known for their ability to absorb and retain large amounts of water relative to their size, which is beneficial in improving soil moisture retention, especially in arid or drought-prone areas. The statistically significant increase in soil moisture observed in this study (mean difference of 2.00 cm^3/cm^3) supports Ali *et al.* (2024) research that highlights the effectiveness of hydrogels in improving water availability for plants, particularly in challenging climates. Linking this study to literature, there has extensively been exploration of the potential of hydrogels in combating soil degradation and mitigating the impacts of climate change on agriculture. Studies [such as Oladosu *et al.* (2022); Albalasmeh *et al.* (2022); Adjuik *et al.* (2022)] have demonstrated that hydrogels can reduce water evaporation, increase water infiltration, and enhance root growth by providing a consistent moisture supply to the plant. The results of this study corroborate these findings, showing that the hydrogel application resulted in a substantial improvement in moisture content, further suggesting its potential as a valuable technology in sustainable agricultural practices.In the context of climate adaptation strategies, hydrogels offer a promising solution for maintaining soil fertility and ensuring crop productivity under fluctuating weather conditions. Noted also from Patra *et al.* (2022), as climate change leads to more frequent droughts and irregular rainfall, hydrogels can play a pivotal role in increasing the resilience of agricultural systems. Hence, the results from this study suggest that hydrogels could be a viable option for adapting to these challenges by improving soil's ability to retain moisture, thereby helping farmers to better manage water resources and reduce the negative impacts of climate variability on crop yields.

Optimal Hydrogel Quantity and Application Method: A Chi-Square test was conducted, and the results provided valuable insights into the relationship between hydrogel treatment and seedling survival rates under varying conditions. The test aimed to determine whether hydrogel application significantly influences seedling survival, a critical factor in agricultural sustainability and climate adaptation. The Pearson Chi-Square and Likelihood Ratio tests yielded p-values of 0.047 and 0.036, respectively, both of which are below the conventional threshold of 0.05 (as in Table 3). These findings suggest a significant association between hydrogel treatment and seedling survival, supporting the hypothesis that hydrogel application positively impacts seedling growth and resilience. The Chi-Square test is a statistical method used to examine the relationship between categorical variables. In this study, it was applied to assess whether hydrogel treatment was associated with seedling survival rates across different conditions. However, it is important to note that the test indicated that 36 cells (100%) had an expected count less than 5, suggesting that the data may be sparse and could influence the robustness of the test. Despite this, the low p-values from both the Pearson Chi-Square and Likelihood Ratio tests provide strong evidence for the positive effect of hydrogel on seedling survival.

Table 3: Chi-square results of seedling survival rates after hydrogel application

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	24.000[a]	22	.047
Likelihood Ratio	26.367	22	.036
N of Valid Cases	12		

a. 36 cells (100.0%) have expected count less than 5. The minimum expected count is .33.

The positive association between hydrogel treatment and seedling survival (through withering off with time) in this study is consistent with the broader body of literature, which highlights the benefits of hydrogel in improving water retention and promoting plant growth under challenging environmental conditions [for example, Oladosu *et al.* (2022); Ali *et al.* (2024); Wu *et al.* (2024); Liu *et al.* (2022)]. Previous studies have demonstrated that hydrogels can reduce water evaporation from the soil, improve water infiltration, and ensure a steady supply of moisture to plant roots, even during dry periods (Ashraf *et al.*, 2021; Chouhan *et al.*, 2023; Tariq *et al.*, 2023; Neethu *et al.*, 2018). This improves soil structure and enhances seedling survival, particularly in regions affected by climate change. The present study corroborates these findings, with hydrogel application showing a significant impact on *Melia volkensii* seedling survival across various conditions, likely due to its ability to maintain moisture levels in the soil.

As climate change leads to increasingly erratic weather patterns, with longer periods of drought and unpredictable rainfall, the need for climate adaptation strategies in agriculture has become more urgent (Anwar *et al.*, 2013). Hydrogels offer a promising solution for maintaining soil moisture during dry spells, thereby supporting plant growth and ensuring crop productivity in water-scarce regions. By improving soil-water retention, hydrogels can reduce the reliance on frequent irrigation, which is increasingly unsustainable due to limited water resources.

In the context of tree planting for climate adaptation, hydrogel-treated soil (provided by the findings) can enhance plant establishment and survival, particularly in arid and semi-arid regions. As also indicated by Ali *et al.* (2024), hydrogels help young plants to establish deeper root systems by providing consistent moisture, which is essential for their survival in challenging climates. Furthermore, studies have suggested that hydrogels can contribute to soil carbon sequestration, further supporting their role in climate change mitigation (Adjuik *et al.*, 2023). Also providing a significant finding is the Multivariate Test of the Two-Way ANOVA that determined the survival rates and further showed a p-value for all tests of 0.000, which indicates that the effect of hydrogel application on survival rates is highly significant at any conventional significance level (e.g., 0.05) as follows.

Table 4: A multivariate test for effect of hydrogel application on survival rates

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	1.000	4952.830[b]	12.000	14.000	.000
	Wilks' Lambda	.000	4952.830[b]	12.000	14.000	.000
	Hotelling's Trace	4245.283	4952.830[b]	12.000	14.000	.000
	Roy's Largest Root	4245.283	4952.830[b]	12.000	14.000	.000

a. Design: Intercept; b. Exact statistic: In this case, there is strong statistical evidence that hydrogel application significantly affects survival rates. All multivariate tests (Pillai’s Trace, Wilks’ Lambda, Hotelling’s Trace, and Roy’s Largest Root) have confirmed the robustness of this finding. Affirming these findings, existing literature has detailed the value of hydrogels in soil and plant management. According to a study by Patra *et al.* (2022), hydrogel application significantly improved soil moisture retention and seedling growth in both greenhouse and field conditions. Similarly, Liu *et al.* (2024) highlighted the role of hydrogels in enhancing plant resilience to drought stress, particularly in desert environments. These studies provide additional support for the findings of this research, reinforcing the notion that hydrogels are a valuable tool in climate adaptation strategies, especially for maintaining soil moisture and supporting plant survival in adverse conditions.

Broader Implications: The application of hydrogel in climate and agricultural practices not only enhances soil-water retention and young crop or seedling survival but also aligns with global climate frameworks such as the Kyoto Protocol, as well as national and international sustainability goals. Hydrogel’s capacity to improve soil moisture retention supports a range of climate adaptation strategies, contributing to carbon sequestration and perfecting ecosystem resilience (Abdallah *et al.*, 2021), both of which are key components of sustainable development efforts.

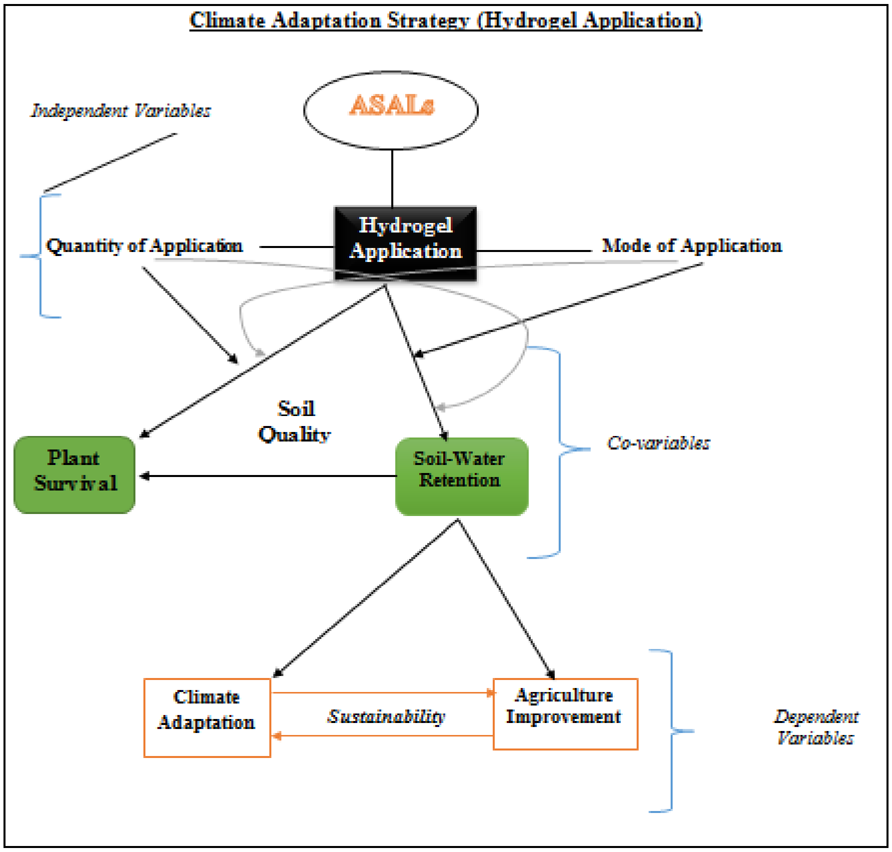

Fig. 2: Study's conceptual framework: A view of climate adaptation strategy with the use of hydrogel.

Hydrogel Technology In the Kyoto Protocol: The Kyoto Protocol, an international treaty aimed at reducing greenhouse gas emissions and promoting climate change mitigation (Garcia-Oliva and Masera, 2004), points out the importance of carbon sequestration through enhanced vegetation cover. Hydrogels takes a significant role in achieving the Protocol's objectives by improving plant growth and survival, especially in regions affected by water scarcity and climate change. By enabling plants to survive in harsh conditions through consistent water availability, hydrogel treatment can help increase vegetation cover in degraded or arid lands as also depicted from the findings of this study. This, in turn, contributes to carbon sequestration, as plants absorb and store carbon dioxide from the atmosphere during their growth cycle. In this way, hydrogel application can support the broader goals of the Kyoto Protocol, particularly in terms of reducing the negative impacts of climate change through sustainable agricultural practices that enhance carbon storage (Maraveas *et al.*, 2023).

Hydrogel Technology in Kenya's NCCAP: Hydrogel application is also in alignment with Kenya's NCCAP, which emphasizes climate adaptation measures, water resource management, and land restoration (Pal and PL, 2022). One of the key objectives of the NCCAP is to address water scarcity, which is increasingly becoming a major challenge in the country due to erratic rainfall patterns and prolonged droughts. In improving soil-water retention, hydrogel helps mitigate the effects of water scarcity on agricultural productivity, particularly in the dryland areas of Kenya. This application is especially valuable for maintaining crop and tree seedling survival during periods of drought, thus improving food security and livelihoods in vulnerable communities. Furthermore, hydrogel contributes to land degradation control by enhancing soil structure and promoting vegetation growth, which is essential for the restoration of degraded lands, another priority outlined in the NCCAP. Overall, hydrogel technology supports Kenya's efforts to combat climate change, adapt to water scarcity, and restore degraded lands, making it an important tool in the country's climate action framework.

Hydrogel Technology in SDGs: Hydrogel technology also aligns with the UN SDGs, particularly SDG 6 (Clean Water and Sanitation) and SDG 15 (Life on Land). SDG 6 focuses on improving water efficiency and ensuring universal access to clean water (Arora and Mishra, 2022). Hydrogels help achieve this by reducing water evaporation and improving water retention in the soil, thereby enhancing water use efficiency. This is especially important in regions where water resources are limited and droughts are frequent. By improving soil moisture retention, hydrogels reduce the need for excessive irrigation, making water use more sustainable and contributing to the achievement of SDG 6.

In addition, hydrogel technology contributes to SDG 15, which aims to protect, restore, and promote the sustainable use of terrestrial ecosystems (Kasoju and Sunilkumar, 2024). Hydrogels improve ecosystem resilience by enhancing soil quality, reducing erosion, and supporting vegetation growth in degraded or dryland areas. As a result, they help foster more resilient ecosystems that are better able to withstand the challenges posed by climate change, such as increased droughts and irregular rainfall. Moreover, the increased vegetation cover supported by hydrogel treatment contributes to biodiversity conservation and ecosystem restoration, both of which are central to SDG 15.

Conclusion: Hydrogel application offers a promising and sustainable solution to enhance soil-water retention and plant survival, particularly in ASALs where water scarcity and soil degradation are prevalent. The results demonstrate that hydrogel significantly improves moisture retention, thereby promoting plant growth and resilience under harsh climatic conditions. This not only supports agricultural productivity but also contributes to global and national climate policies, aligning with the Kyoto Protocol, Kenya's NCCAP, and the achievement of SDG 6 and SDG 15. In reducing water consumption and enhancing ecosystem resilience, hydrogel aids in achieving LDN and advancing climate adaptation efforts. However, further research is needed to assess the long-term effects of hydrogel application, its scalability across diverse ecosystems, and its potential to integrate with other sustainable agricultural practices. This would ensure its effectiveness as a climate-resilient strategy on a broader scale.

Declaration of Conflict of Interest: The authors declare that they have no conflict of interest related to this research.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data were obtained through primary data collection conducted by the corresponding author.

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