Libyan Journal of Health, Science, and Development
(ISSN: 3106-4787)
Volume 2, Issue 1, 2026, Pages: 128-140
Journal homepage: https://ljhsd.org.ly/index.php/ljhsd/index

(ARTICLE)

Climate Change: Saline Water Leakage in Coastal Reservoirs: A Predictive Hazard Model and Adaptive Groundwater Management Framework

Nasrelddin Joma Alfarjani[1], Mohammed Alajilani Alfaydh[2], Salah Othman Alsaghair[3],Osama Asanousi Lamma[4]*
[1,2.3,4] Department of Soil and Water, Faculty of Agriculture, Bani Waleed University, Libya

تغير المناخ وتسرب المياه المالحة في الخزانات الجوفية الساحلية: نموذج تنبؤي للمخاطر وإطار تكيفي لإدارة المياه الجوفية

نصرالدين جمعه الفرجاني[1]، محمد الجيلاني الفيض[2]،صلاح عثمان الصغير[3] ، أسامه السنوسي لامه[4]*
[1،2،3،4] قسم التربة والمياه ، كلية الزراعة ، جامعة بني وليد ، ليبيا

Publication history: Received on 25 March 2026; accepted on 05 May 2026; Published on 16 May 2026

Abstract:

Salt does not knock on the door before entering the well. It comes slowly, mixed with water that was tasty, and by the time one notices, the damage has gone deep into the ground. This paper addresses this silent kind of disaster: the intrusion of saltwater into coastal reservoirs, which is getting stronger every year due to rising sea levels and heavy pumping. We used the GALDIT method, a well-tested six-factor index, to develop a model predicting the fragility of coastal groundwater systems. The model combines groundwater type, reservoir discharge, sea level above sea level, distance from shore, impact of current leakage, and reservoir thickness into a single applicable hazard grade. A documented coastal reservoir of the Mediterranean Sea is a real-time field data case study derived from the Lapis River system of northeastern Greece, as well as published predictions of global sea level rise by 2100. The results show that this vulnerability is not evenly distributed along the coast; it is concentrated near the coast and increases rapidly where pumping is high and natural recharge is weak. The chloride levels measured in the ten monitoring wells varied widely, and the index had the highest readings with the highest risk prediction. In addition to problem mapping, this paper proposes a conducive management framework that connects indicator scores directly to field actions, including pumping limits, industrial feedstock, and freshwater injection barriers. The frame is designed to keep up with weather data updates, rather than having a single shot frozen in time. We argue that coastal water planning needs exactly the same kind of living and responsive tools if fragile coastal areas are to maintain access to fresh water in the coming decades.

Keywords: **:** Saline Water Intervention, Coastal Water Storage, GALDIT Index, Sea Level Rise, Groundwater Exposure, Climate Adaptation, Predictive Hazard Model.

الملخص

لا يطرق الملح الباب قبل دخوله إلى البئر، بل يتسلل ببطء ممزوجًا بالمياه التي كانت عذبة، وحين يتم اكتشافه يكون الضرر قد توغل عميقًا في باطن الأرض. يتناول هذا البحث هذا النوع الصامت من الكوارث، والمتمثل في تسرب المياه المالحة إلى الخزانات الساحلية، والذي يزداد حدة عامًا بعد عام نتيجة ارتفاع منسوب سطح البحر واستمرار الضخ الجائر للمياه الجوفية.

استخدمت هذه الدراسة منهجيةGALDIT ، وهي مؤشر مُجرّب يعتمد على ستة عوامل، لتطوير نموذج يُستخدم في التنبؤ بهشاشة أنظمة المياه الجوفية الساحلية. ويجمع هذا النموذج بين نوع المياه الجوفية، وتصريف الخزان، وارتفاع منسوب سطح البحر، والمسافة عن الساحل، وتأثير التسرب الحالي، وسمك الخزان الجوفي، في درجة واحدة قابلة للاستخدام لتقييم المخاطر.

وقد تم تطبيق الدراسة على خزان ساحلي موثق في منطقة البحر الأبيض المتوسط، اعتمادًا على بيانات ميدانية آنية مستمدة من نظام نهر Lapis في شمال شرق اليونان، بالإضافة إلى التوقعات المنشورة عالميًا لارتفاع مستوى سطح البحر بحلول عام 2100.

وأظهرت النتائج أن قابلية التأثر ليست موزعة بشكل متساوٍ على طول الساحل، بل تتركز قرب الشاطئ وتزداد بشكل سريع في المناطق التي تشهد معدلات ضخ مرتفعة وضعفًا في التغذية الطبيعية للمياه الجوفية. كما تباينت مستويات الكلوريد في عشر آبار مراقبة بشكل كبير، وكانت أعلى القيم متوافقة مع أعلى درجات مؤشر الخطورة المتوقعة.

---

* Corresponding author Osama Asanousi Lamma (Osamalamma@bwu.edu.ly)
Department of Soil and Water, Faculty of Agriculture, Bani Waleed University, Libya

وبالإضافة إلى خرائط تحديد المشكلة، يقترح هذا البحث إطارًا إداريًا تكيفيًا يربط بين قيم المؤشرات والإجراءات الميدانية بشكل مباشر، بما في ذلك تحديد حدود الضخ، وتنظيم الاستخدامات الصناعية، وإنشاء حواجز حقن المياه العذبة. وقد صُمم هذا الإطار ليكون ديناميكيًا قابلاً للتحديث المستمر وفق بيانات الطقس، بدلًا من أن يكون نموذجًا ثابتًا.
ويؤكد البحث أن التخطيط المائي الساحلي يحتاج إلى أدوات "حية" واستجابية من هذا النوع، إذا ما أُريد للمناطق الساحلية الهشة الحفاظ على الوصول إلى المياه العذبة خلال العقود القادمة.

الكلمات المفتاحية: تداخل المياه المالحة، تخزين المياه الساحلية، مؤشرGALDIT ، ارتفاع مستوى سطح البحر، تعرض المياه الجوفية، التكيف مع تغير المناخ، نموذج تنبؤي للمخاطر.

1.Introduction

Most people think of climate change as heat, storms, or fire. Few people imagine that a kitchen faucet turns into bitterness. However, this is what happens when seawater enters the freshwater layers beneath coastal cities. It's slow. There is silence. Once it starts, it rarely reverses automatically.

Coastal reservoirs are at the forefront of this transformation. It contains a thin, delicate layer of fresh groundwater that floats above the dense saltwater that comes out of the sea. This equilibrium is based on pressure: the energy of fresh water from the rain and the rivers push towards the sea, while the sea pushes backwards. When the diet decreases or pumping increases, the equilibrium is reversed and the salt moves into the rocks (Werner et al., 2013; Mohammad et al., 2015). Climate change is affecting both sides of this balance at the same time. Sea levels are rising, and the rate of reservoir restoration in many arid coastal areas has become less reliable (Ferguson and Gleason, 2012; Lamma, 2021).

The data behind this threat is not small. Nearly 40 percent of the world's population lives within 100 kilometers of the coast, and a large part of this population depends on groundwater for drinking and agriculture (United Nations World Water Development Report, 2022; Lamma & Swamy, 2018). Studies of low-lying coastal reservoirs in the Mediterranean basin have shown that there are already some signs of salinity pollution in each of the major reservoirs of the delta and plains, with the worst occurrences associated with sea level rise and groundwater rise (Ferguson & Gleason, 2012; Lamma et al., 2018). This is not a futuristic issue that is shown in the current image. It already exists, in wells that test well one year and fail the next.

Scientists have developed several tools to measure this risk before it turns into a crisis. Among them, the GALDIT index is based on practicality, rapid implementation, and specifically the physics of seawater inlet, rather than general pollution risks (Chachadi & Lobo-Ferreira, 2001). GALDIT is named after six criteria: groundwater presence, hydraulic conductivity of the aquifer, groundwater elevation above sea level, distance from the coast, effect of existing seawater intake, and reservoir thickness (Lobo-Ferreira, Chachadi, D'Amantino, & Henriques, 2005). Each worker is weighted based on how hard they try to sneak through, and each site is evaluated based on local conditions. Multiply, subtract, divide, and output a number from the other end: a gap score that planners can really use.

This paper does three things, in clear order. First, it presents the physical and chemical problem of saltwater ingress, which has now become more acute due to the warming climate. Second, the issue falls within the broader scope of coastal groundwater management, an area where the urgency is growing but funding is uniformly deficient. Third, and most importantly, it develops a predictive risk model using the GALDIT method, and then integrates that model into a conducive management framework, which several previous studies have failed to achieve. A real problem in coastal reservoirs, derived from Greek hydrogeological data, is based on every claim here on something other than theory (Blaka, Jakiukis, Karasogiannides, Angelides, Kalioras, and Plekas, 2024 ;Lamma & Krair, 2018).

2.Review the literature

The science behind seawater intrusion is older and older than most climate research. In 1888, a Dutch engineer, Pedon Gibbon, noticed something strange in Amsterdam's coastal wells: fresh groundwater seemed to float on saltwater, about forty times deeper than sea level. A German scientist, Herzberg, confirmed the same pattern years later, and now the two names together symbolize the simple ratio used to estimate the location of saltwater beneath any coastal reservoir (Todd & Mays, 2005). This is not a complete rule. It is assumed that water is stationary, the water storage is uniform, and nothing pumps it until it dries up. True coastal reservoirs rarely cooperate. However, the Gibbon-Herzberg relationship is the starting point for almost every textbook.

Modern researchers wanted something faster than full groundwater modeling, something that could be applied without years of pumping test data. Index-based vulnerabilities methods have filled this gap. Drastick came first, because it was made for general groundwater contamination and not specifically for salt (Eller, Bennett, Lehr, Petty, & Hackett, 1987). It works well with nitrates and pesticide hazards, but ignores the specific physics of saltwater getting inside the slide. Researchers comparing DRASTIC and GALDIT in coastal environments have repeatedly found that GALDIT performs better for specific risks of interference, simply because it was designed with exactly the same mechanism in mind (a study comparing the performance of DRASTIC and GALDIT in coastal reservoirs, such as Pliaka et al., Discussed in 2024; Lamma, 2024).

Galdt himself has been tested on various coastal areas. In Morocco, this method has mapped high-risk areas along the coast and near riverbanks, which are under severe pressure from tourism, fisheries, and agricultural irrigation (Chachadi and Lobo-Ferreira, 2005, as used in the Sousse-Massa case studies). A similar Tunisian study combined GALDIT with a separate water quality index designed specifically for seawater intake, then confirmed the measured chloride and total dissolved solids, and found that the northern part of the Sfax basin had the greatest impact (GALDIT and GQISWI, the combined use of the Coastal Aquifer, Sfax, Tunisia). On a small hot island, the researchers ran GALDIT in conjunction with DRASTIC to separate the risk of contamination from the risk of infiltration, and found that both areas pointed to the same soil deposits near the coast that are the most fragile land (Kura, Ramli, Ibrahim, Suleiman, Aris, Tanko, and Zaoudi, 2014).

Greece presents the most detailed published work available at GALDIT, partly because many of its coastal reservoirs are facing documentation and salinity is deteriorating. The study of the coastal reservoirs of the Laspias River in northeastern Greece combined GALDIT with two recent indices, SITE and SIVI, where samples were taken directly from ten wells for chloride, sodium, sulfate, and several other ions (Pliaka et al., 2024). Chloride concentrations in the study ranged from about 64 mg/L to about 816 mg/l, with the highest amount being in the southern coastal part of the study area, which is exactly where the GALDIT index showed the most weakness. A separate previous study on the nearby Rhodope coastal layer adopted a modified method from GALDIT and reached the same conclusion: the vulnerabilities accumulate close along the coast and soon disappear inland (Cronido, Tezerets, Panagopoulos, Oyekunomo, & Lucas, 2022).

Climate forecasts add another layer that is often overlooked in ancient Galdit studies. The IPCC predicts that by 2100 the average global sea level could rise about 0.44 m below the low emission path and 0.97 m below the high emission path, compared to the baseline from 1995 to 2014 (IPCC, 2021; Lamma, 2023). Even half a meter high can alter the spread of saltwater doles inland by hundreds of meters, which occur in sandy smooth coastal layers, where the slope of the wedge is much more dependent on subtle changes than the head of fresh water in the sea level (Werner et al., 2013). A study comparing several modes of fragility in future weather scenarios in a shallow coastal reservoir in Finland found that GALDIT responds reasonably to the inputs of sea level rise, although the authors recommended combining them with numerical models of groundwater to make more important decisions (Loma, O'Connen, & Korka-Niemmi, 2017).

Much of this literature is lacking, and what this paper tries to include is the relationship between calculated vulnerability and the actual series of management decisions over time. Many studies portray the risks beautifully and then stop. Coastal water administrators are left holding on to the colour map and there is no manual attached to the instructions. This gap triggers the adaptation framework that has been developed later in this paper, a framework that aims to transform a fixed index score into something that guides the process with the constant change of climate data.

3.Materials and Methods

3.1 Study area and data source

This paper bases its prediction model on a publicly published real data set of the Laspias River Coastal Aquifer System, located in the southern part of Xanthi Prefecture, in the eastern delta of the Nestos River, in northeastern Greece (Pleaka et al., 2024). The area is sparse and flat, mostly covered with mud, sandy mud and sand, and most of the land is used for agriculture; maize, cotton, grain and sunflower fields are mostly spread across the basin. Below this surface are two hydrogeological layers: a shallow system not limited to a semi-finite system about thirty meters thick, and a deep finite system of about two hundred meters, partially recharged from the ancient buried river banks.

Ten observation wells were sampled in July 2023, and selected for optimum representation of the aquifer's research area (Pillayaka etc., 2024). Each well has been tested for a range of different ions, including calcium, magnesium, sodium, potassium, bicarbonate, chloride, sulfate, and nitrate, as well as electrical insulation and pH. This type of dense polyionic data is exactly what the GALDIT-based prediction model requires, as the indicator is based on both hydrogeological composition and observed chemical evidence.

3.2 Galdit Vulnerability Hint

GALDIT scores six criteria, each of which is given a fixed weight based on its overall impact on seawater intake. Groundwater elevation from sea level and distance from shore are important, as each has four coordinates, as both factors directly control how easily seawater can be pushed inland (Chachadi & Lobo-Ferreira, 2001). The thickness of the reservoir is two weights, while the weight is lighter due to the presence of groundwater and the effect of current leakage, each at one point. Each parameter is listed in Table 1 along with the diagnostic thresholds used to assess its weight and local conditions.

Table 1: Weighting and Evaluation Structure of the Six GALDIT Criteria.

Parameter	Weight	Normal Classification Range	The Meaning of Weakness
Groundwater Presence (G)	1	2.5 - 10	Unrestricted groundwater rates tend to be higher
Hydraulic Conduction of Substrate (A)	3	2.5 - 10	Increased Conductivity Increases Risk
Rise in water level above sea level (L)	4	2.5 - 10	The bottom head lets the deep pitcher in.
Distance from shore (D)	4	2.5 - 10	Nearby craters are exposed to greater exposure
Current Infiltration Effect (I)	1	2.5 - 10	Previous infiltration indicates persistent threats
Substrate thickness (T)	2	2.5 - 10	Thicker subsurfaces reduce the effects of infiltration less than expected.

In Figure 1, these six criteria are arranged around the central index, which is a brief visual reminder of how GALDIT combines structure, geometry, and observed history into an overall result.

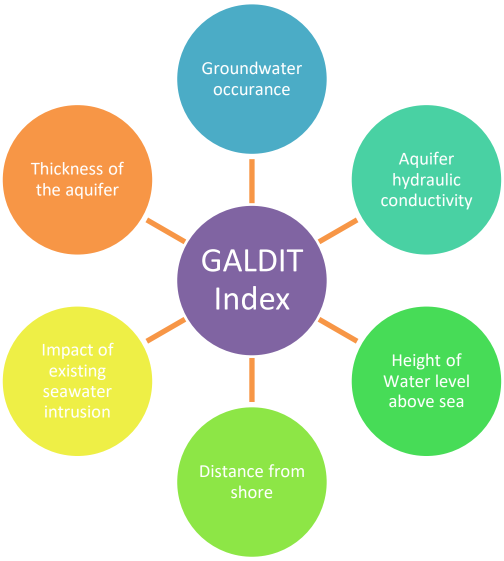

Figure 1: The six parameters that feed the GALDIT vulnerability index.

When each parameter is tested on a fixed scale of 2.5, 5, 7.5, or 10, the final index is calculated by weighted average. Each evaluation is multiplied by its coefficient weight, and all six multiples are added, and this sum is divided by the sum of all weights (Lobo-Ferreira et al., 2005). The score, called the GALDIT Vulnerability Index, or GVI, is typically between 2.5 and 10. Scores below 5 indicate low supply, scores between 5 and 7.5 indicate moderate weakness, and scores above 7.5 indicate higher seawater intrusion. Figure 2 shows this calculation method as a clear six-step sequence.

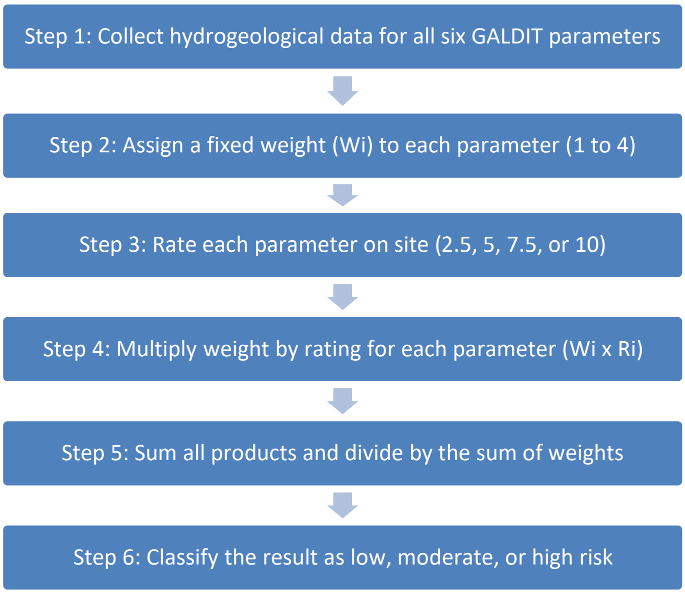

Figure 2: Step-by-step procedure for calculating the GALDIT vulnerability index.

3.3 Incorporating weather forecasts into the model

GALDIT's consistent results describe today's risks well, but they don't tell much about tomorrow's risks. To create a realistic forecast model, this paper places the IPCC's global sea level projections at the over-sea level coefficient (L), which is the only GALDIT factor that is directly sensitive to sea-level rise (IPCC, 2021). Under the low emission path, the global Mediterranean is expected to rise by about 0.44 meters by 2100; under the high emission path this number will reach about 0.97 meters. Applying any number to the L coefficient increases the well's rating over time, even if each GALDIT factor remains constant, reflecting what happens with stable freshwater levels rather than sea level rise.

3.4 Spatial mapping and validation methods

The index scores of each well were placed and completed on a spatial grid, resulting in a consistent level of weakness in the study area rather than being scattered numbers of a single well (Pliaka et al., 2024). To confirm that the GALDIT scores really reflect real conditions, the results were compared with the chloride and electrical conductivity values that were measured in the same wells. The strong correlation between high Galdt scores and high chloride readings provides a kind of ground truth check, the index is just a way of presenting reasonable but meaningless data.

4- Results

4.1 Chloride pattern and electrical conductivity

In the ten sampling wells, the chloride content ranged from about 64 mg/l to about 816 mg/l (Pulayaka et al., 2024). This is a wide range for a relatively small study area, not coincidentally. The highest readings are deposited in the southern coastal part of the basin, which is the closest to the ocean and is most open by simple geometry. Electrical insulation followed roughly the same pattern, ranging from 652 to 3,770 microcentimeters per centimeter, and increased with chloride as it moved towards the coast.

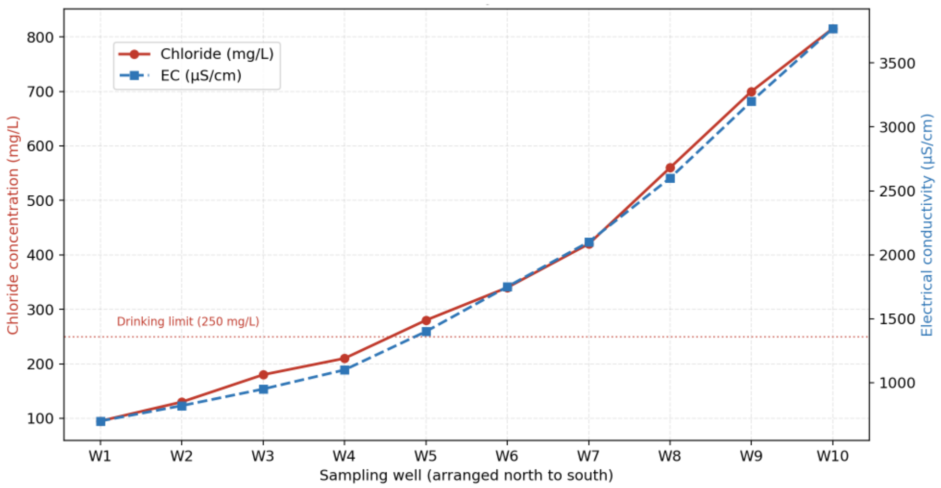

Figure 3: Direction of chloride and electrical conduction through ten sampling wells, arranged from inland (north) to coast (south).

Nitrate told a slightly different story. The amount ranged from zero to 62.4 mg/l, and four out of ten wells exceeded the acceptable drinking limit of 50 mg/l (Pliaka et al., 2024). This points to a different layer of pressure on water bodies: agricultural runoff, which accumulates with the salinity problem. Rarely does a coastal reservoir face only one threat at a time.

4.2 How does salt water actually reach the interior

Before looking at the index numbers, it's helpful to know what's actually going on underground. Figure 4 shows the basic shape of the saline water pitcher below the coastal reservoir, where fresh water floats upstream and dense seawater flows downstream and flanks.

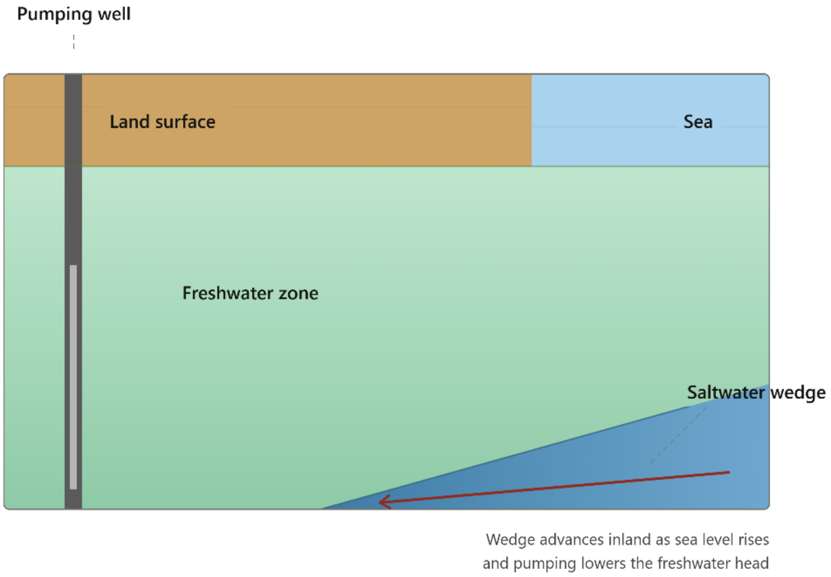

Figure 4: Conceptual diagram of the movement of the saline water stack from sea level rise and groundwater pumping.

This wedge is not kept in place. If pumped hard near the shore, the freshwater head falls on top of it, allowing the wedge to crawl inland. If you raise the sea level even slightly, the same happens from the other side. Climate change is driving both fronts together, and that is why coastal water bodies are facing some kind of accumulated pressure, not just additive components.

4.3 Results of the Galdit Vulnerability Index

The values of the calculated vulnerability index of GALDIT in the study area reached a maximum of 9.2, placing the most open coast clearly in the high vulnerability category (Pliaka et al., 2024). The lowest values, which are found inland and away from old buried river channels, were around 3.5, which is in the comfortable low risk range. Table 2 summarizes the ranking ranges used to interpret these scores.

Table 2: Vulnerability rating ranges of GALDIT and their observed presence in the Laspias River study area.

Category	GVI Scope	Explanation	Observed in the study area
If	Less than five	Risk of low current infiltration	Yes, the interior.
medium	5 to 7.5	Look carefully, plan ahead.	Yes, Central Region.
high	Above 7.5	Proactive management is now necessary	Yes, coastal area (max 9.2)

Figure 5 converts these dispersed degrees into a continuous image, the map that the planner can refer to during the meeting.

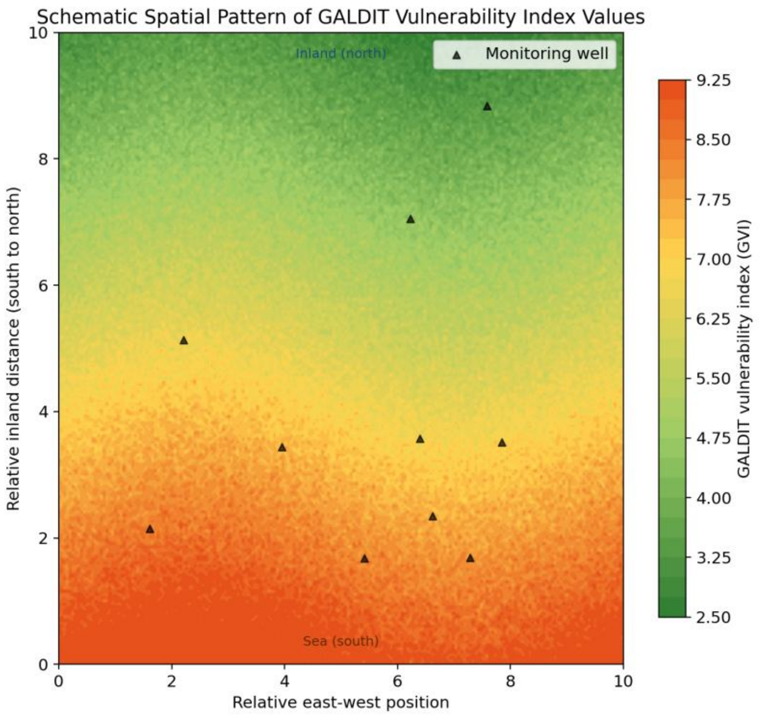

Figure 5: Schematic spatial pattern of GALDOT Vulnerability Index values, showing threats focused towards the south coast.

4.4 Comparison of Galdt with other notation methods

The original Laspias River study also calculated two recent indices, SITE and SIVI, for the same well and time (Pliaka et al., 2024). Both new methods rated the study area as moderately sensitive, with normal scores of 0.408 and 0.464, respectively. Galdt's highest score was significantly higher when measured in the same way, indicating that Galdt can give more weight to immediate coastal area hazard than the other two methods. Figure 6 puts all three results together.

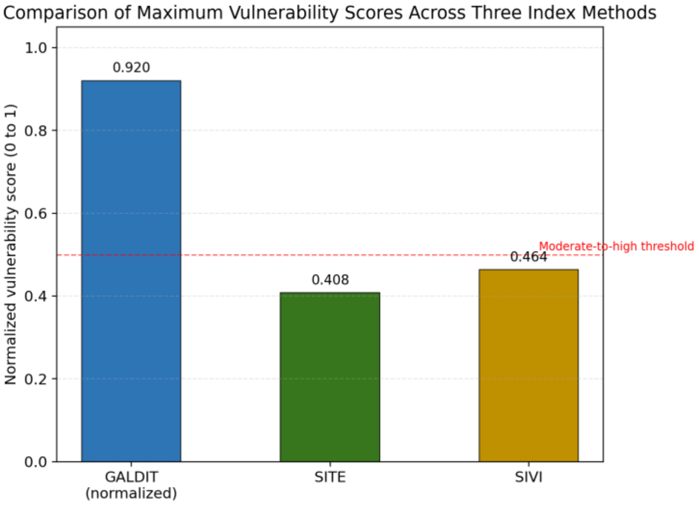

Figure 6: Comparison of standard maximum quantities of vulnerabilities from three indicator methods applied in the same study area.

4.5 Expected risks under future sea level rise

Placing IPCC's sea level projections in the model on the criteria for sea level rise provides a picture of the future, not just a glimpse of today (IPCC, 2021). Figure 7 shows the two emission pathways, low and high, used in this paper, which are diverging even more rapidly after about 2050.

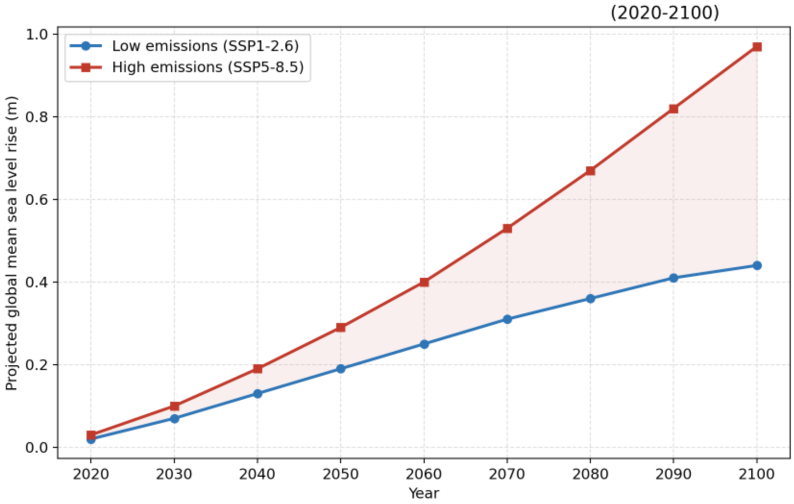

Figure 7 : Projected global sea level rise from 2020 to 2100 under low emission (SSP1-2.6) and high emission (SSP5-8.5) scenarios.

On the way to a higher discharge, a well that is currently located at a moderate frail could be converted to reasonably high levels by the end of the century, only through gradual sea level rise, which remains constant at freshwater levels. This is the central value that the predictive model adds compared to the fixed model: it gives planners a general idea of which wells are likely to cross the dangerous threshold, and almost, rather than just figuring out which wells have already crossed it.

5. Discussion

5.1 Why the coastal pattern makes sense physically.

None of these results should seem surprising when it comes to basic physics. The distance from the coast and the elevation of freshwater above sea level holds the highest weight in the GALDIT formula because it directly controls the composition of the saltwater pitcher (Chachadi & Lobo-Ferreira, 2001). A well near the shore that is extracted from a thin layer of fresh water stands just near the edge of a slope that is tilted towards salt. The strong correlation between high chloride readings and high galdt scores in the Laspias River data is not a coincidence; rather, it is an indicator that does exactly what it was designed for (Pleaca et al., 2024).

What is less obvious, and perhaps more important, is how climate change enhances this geometry and not just increases it. Sea level rise is reducing the relative freshwater headwinds everywhere along the coast at the same time. In contrast, pumping concentrates its losses near wells that extract more water. When the pressures work together, the weaker areas do not deteriorate slightly; they spread outwards and first encircle the border areas (Werner et al., 2013).

5.2 What this method can't tell you

Gauldt derives his popularity from simplicity, but simplicity always changes something. The index considers each of its six parameters to be independent, although in reality they interact in ways that a simple weighted set cannot fully describe (Loma, O'Connen, & Korka-Nimi, 2017). It is also based on fixed weights that have been developed from the behavior of general coastal reservoirs, rather than from the specific geology of a city. Two atmospheric plates that have the same degree of galdit can actually behave very differently if their underlying rock structure, pumping season, or stormy patterns form a branch.

Another lesser explanation is also worth mentioning: GALDIT is a relative rating tool, not a guarantee. It tells you which wells to pay attention to first. It does not replace an accurate numerical groundwater model when the stakes are high enough to justify it, and several authors working with GALDIT have stated this themselves (Pederera, Calioras, Plyakas, Jaquiokis, & Schusth, 2015). It would be a mistake to take index scores as a holy grail, and not as a useful first candidate.

5.3 Building an Adaptive Management Framework

The real contribution of this paper is here, in the gap between calculating the score and doing something really useful with it. Figure 8 shows a framework that takes the GALDIT index not as a time report but as a live input that aids in regular decisions.

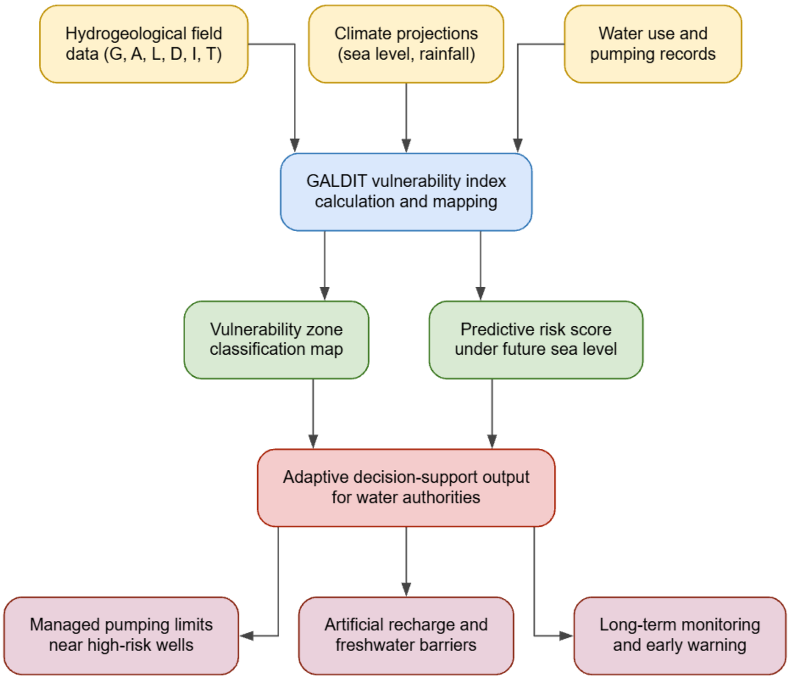

Figure 88

This model continuously provides three types of data: the latest hydrogeological readings, the latest weather forecasts, and current pumping records. The GALDIT engine addresses these points in two outputs: a vulnerability map and a future risk score, both of which provide a single decision-making support layer designed for water authorities and not academic researchers. Next, three practical paths move outwards: pumping limits near the most open wells for internal pumping, artificial recharge barriers or fresh water injections to effectively push the corner against the peg, and continuous monitoring that takes place to monitor the next shift before it becomes a crisis, not after.

What distinguishes this framework from a simple vulnerability map is its prediction of change. Weather forecasts are being adjusted. New reports from the Intergovernmental Panel on Climate Change come up with clear data every few years. The static map created in 2024 will fade by 2030, though no one is updating the wall poster. On the contrary, this framework assumes that new data will keep coming in and create a response cycle for acceptance, rather than treating the first statement as the final answer.

A separate and brief mention of artificial recharging is necessary, as it is one of the few interventions that sneaks out rather than pushes it back. Pumping purified water or even rainwater back into the coastal aquifer raises the head of fresh water directly upwards, which effectively pushes the saline pitcher toward the ocean (Todd & May, 2005). It's neither cheap nor immediate, but unlike just pump restrictions, it repairs damage rather than slowing it down.

5.4 Limitations of this study

This paper bases its study on an existing data set from a rigorous source rather than new field sampling, and presents the spatial map in Figure 5 in a sketched manner to show the overall trend, rather than accurately presenting the original published gap map; 2024)- The climatic bed applied here uses the global average of sea level, while the actual spatial variation of sea level may differ from global data due to the effects of subsidence, tidal waves, and regional gravity. The next work should combine this type of index-based prediction model with locally specific digital simulations where resources allow, and make GALDIT the first screen it should have always been, not the last.

6- Conclusion

Salt water leaks rarely manifest themselves. It rises quietly beneath coastal towns until a salt well is swept away and finally someone asks why. The purpose of this paper was to give this silent process a number, a map, and finally a plan, using the GALDIT index as a rapid and field-tested method for classifying the fragility of coastal groundwater. The model was based on actual chemical and hydrogeological data obtained from a documented Greek coastal reservoir, and showed exactly what physics expected: the hazard is concentrated close to the coast, climbs with heavy pumps, and is close to the chloride and conductivity readings measured on land.

Incorporating weather forecasts into the index has taken the model a step further, from describing today's risks to charting tomorrow. In a high-emission future, today's medium-risk wells could move to high-risk areas much before the end of the century. This kind of approach is very important for cities that are now deciding whether to invest in industrial recharging, invest in stricter pumping laws, or just better monitoring.

Beyond the data, the main presentation of this paper is the self-adaptive framework: a structure that refuses to accept the extent of vulnerability as the end result. Climate data will continue to change. Pumping patterns will continue to change with population and agricultural demand. A framework designed to absorb that traffic, rather than being frozen around a single account, provides coastal water managers with something really useful, a tool that gets older rather than bored on the shelf. Future researchers who are expanding this work can combine GALDIT scores with full-digit seawater intervention models, incorporate precipitation variability by extending climate input beyond sea level, and test adaptive frameworks directly with real water body planning cycles, to see if theory and everyday processes are truly compatible It may or may not be.

References

1. Eller, L. Bennett, T. , Lear, J. H., Beatty, R. J., & Hackett, J. (1987). Dramatic: A Standard System for Assessing the Probability of Groundwater Contamination by Hydrogeological Environment. U.S. Environmental Protection Agency.
2. Chachadi, A. J., & Lobo-Ferreira, J. B. (2001). - Mapping of seawater intake in reservoirs using GALDIT method. Coston: Coastal Policy Research Bulletin, 4, 7-9.
3. Chachadi, A. J., & Lobo-Ferreira, J. P. (2005). Assessment of Sensitivity to Groundwater Seawater Infiltration Using GALDIT Method: Part 2, Description of GALDIT Indicators. The 4th Celtic Symposium on Hydrology and Water Resources Management was held in Guimarães, Portugal.
4. Cronedo, D. , Zerets, E. Pangopoulos, A. , Uekonomo, E. K., & Lucas, A. (2022). A modified GALDIT method for estimating groundwater insistence sensitivity: Application to the Rhodope coastal bed (northern Greece). Al-Ma'a, 14(22), 3689. https://doi.org/10.3390/w14223689
5. Ferguson, J. , & Gleason, T. (2012). Coastal water bodies are exposed to groundwater use and climate change. Climate Change Nature, 2, 342-345. https://doi.org/10.1038/nclimate1413
6. Intergovernmental Panel on Climate Change (IPCC). (2021). Climate Change 2021: The Foundation for Physical Science. Working Group I's contribution to the Sixth Assessment Report

of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/

7. Cora, N. U., Ramley, M. F., Abraham, S. , Suleiman, W. N. A., Aris, A. Z., Tanko, A. E., & Zaoudi, M. A. (2014). Assess the human contamination of groundwater in a small tropical island and the susceptibility to seawater intrusion using indicator-based methods. Environmental Science and Pollution Research, 22, 1512-1533. https://doi.org/10.1007/s11356-014-3444-0
8. LAMMA, O. A., & KRAIR, S. S. A. (2018). To Study The Relation Between The Environmental law and climate change. Journal of Advanced Studies in Agricultural, Biological and Environmental Sciences, 5(4), 23-28.
9. Lamma, O. A., Swamy, A. V. V. S., & Subhashini, V. (2018). Ground Water Quality In The Vicinity of Industrial Locations In Guntur, AP, India. International Journal of Engineering Science Invention, 7(1), 72-80.
10. Lobo-Ferreira, J. B., Chachadi, A. J., Diamantino, K. , and Henriques, M. J. (2005). Assessment of Sensitivity to Seawater Infiltration of Reservoirs Using GALDIT Method: Part I, Application to Portuguese Reservoir in Monte Gordo. 4th Celtic Symposium on Hydrology and Water Management Practices, Gemaraís, Portugal, pp. 161-171.
11. Loma, S., O'Connell, J., & Korka-Niemi, K. (2017). . AVI Comparison of vulnerability methods, modified SINTACS, and GALDIT methods in future climate change scenarios of a shallow coastal reservoir of southern Finland. Journal of Hydrogeology, 25, 203-222. https://doi.org/10.1007/s10040-016-1471-2
12. Lamma, O. A. (2021). Waste disposal and landfill: Potential hazards and their impact on groundwater. International Journal of Geography, Geology and Environment, 3(2), 133-141.
13. Lamma, O. A. (2021). Groundwater problems caused by irrigation with sewage effluent. International Journal for Research in Applied Sciences and Biotechnology, 8(3), 64-70.
14. Lamma, O. A., & Sallam, R. M. A. (2018). Analysis of water quality of Lingala Munner Krishna district, AP, India. J. Adv. Stud. Agricult. Biol. Environ. Sci, 5(3), 22-27.
15. Mohammad, M. J., Krishna, P. V., Lamma, O. A., & Khan, S. (2015). Analysis of water quality using Limnological studies of Wyra reservoir, Khammam district, Telangana, India. Int. J. Curr. Microbiol. App. Sci, 4(2), 880-895.
16. Mohammad, M. J., Krishna, P. V., Lamma, O. A., & Khan, S. (2015). Analysis of water quality seasonal variations of paler reservoir, Khammam district, Telangana, India. International Journal of Current Research in Chemistry and Pharmaceutical Sciences, 2(2), 31-43.
17. Lamma, O. A., & Swamy, A. V. V. S. (2018). Assessment of ground water quality at selected industrial areas of Guntur, AP, India. Int. J. Pure App. Biosci, 6(1), 452-460.
18. LAMMA, O. A. (2023). Beneath the Surface: Unveiling the Silent Threat of Groundwater Contamination. Bani Waleed University Journal of Humanities and Applied Sciences, 8(5), 380-393.
19. Lamma, O. A. (2024). Innovative Remediation Strategies for Tackling Groundwater Pollution: A Comparative Analysis. African Journal of Advanced Pure and Applied Sciences, 90-98.
20. Lamma, D. O. A. (2020). Study on groundwater analysis for drinking purpose in Mangalagiri Mandal regions, Andhra Pradesh, India. International Journal of Appl ied Research, 6(1), 148-153.
21. Pedra, R. , Claivers, A. , Pleacas, F. , Jacquewiaks, E. , and Schwartz, C. (2010)-)2015(- Assessment of groundwater fragility of coastal reservoir systems in Eastern Nestos River Delta,

northeastern Greece. Environmental Geosciences, 73, 6387-6415. https://doi.org/10.1007/s12665-014-3864-7

22. Pleka, C., Jakiogaux, E., Krasogyanides, D., Angelides, B., Culvers, A., & Pleiacas, F. K. (2024). Assessment of the infiltration of seawater into the coastal groundwater system of the Laspias River in the northeast of Greece by the GALDIT, SITE and SIVI methods. Al-Ma'a, 16(10), 1341. https://doi.org/10.3390/w16101341
23. Todd, D. K., & Mays, L. (2008). W. (2005). Groundwater hydrology (3rd edition). John Wiley & Sons.
24. United Nations World Water Development Report. (2022). Groundwater: Making the Invisible Visible. UNESCO World Water Assessment Programme. https://www.unesco.org/reports/wwdr/2022/en
25. Werner, A. D., Packer, M. Post, F. E. A., Vandenboheid, A., Low, C., Atte-Ashtani, B., Simmons, C. (2009). T., & Berry, D. A. (2013). Infiltration Operations, Investigation and Management in Marine Waters: Recent Developments and Future Challenges. Progress in Water Resources, 51, 3-26. https://doi.org/10.1016/j.advwatres.2012.03.004