

Groundwater Vulnerability Assessment Using the GOD Method in the Grombalia Coastal Aquifer, Tunisia: Focusing on the Soliman Lagoon Area

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INTRODUCTION & AIM

Groundwater vulnerability assessment is essential for protecting water resources from diffuse contamination. The GOD method provides a simple yet effective approach based on three intrinsic parameters of the natural environment:

- **G**: Groundwater occurrence (confined vs. unconfined)
- **O**: Overlying lithology (permeability of unsaturated zone)
- **D**: Depth to water table

Aim: To apply the GOD method to the Soliman Lagoon aquifer in the Grombalia coastal plain (Figure 1), classify vulnerability zones, and identify priority areas for protection.



Figure 1. Location map of Soliman Lagoon and Grombalia plain.

METHOD

The GOD index is calculated as:

$$GOD = G \times O \times D$$

Each parameter is assigned a value between 0 and 1:

- **G**: Confined aquifer ≈ 0; unconfined ≈ 1
- **O**: Low permeability (clays) ≈ 0.4–0.5; high permeability (sands) ≈ 0.8–1
- **D**: >50 m depth ≈ 0.6; <5 m depth ≈ 0.9–1

Classification:

- 0.0–0.1: Very low
- 0.1–0.3: Low
- 0.3–0.5: Moderate
- 0.5–0.7: High
- 0.7–1.0: Extreme



Figure 2. Views of Soliman Lagoon (Source: Houda Rzigui, oral presentation 10-06-2025).

GIS-based mapping was used to integrate parameter layers and produce vulnerability maps.

The Soliman Lagoon (Fig.2) area is characterized by a heterogeneous aquifer system, including both confined and unconfined aquifers. Water table depths vary significantly across the area, with deeper levels (>50 m) in the east and southwest, and shallow levels (<20 m) in the center.

The Soliman Lagoon aquifer, part of the **Grombalia coastal plain**, is characterized by a **heterogeneous multi-layered system** comprising:

- **Confined aquifers** in deep alluvial and Miocene sands in the east and southwest.
- **Unconfined shallow aquifers** in central and northern sectors, with water table depths <20 m.

The overlying lithology varies from **low-permeability clayey materials to medium-permeability sands**, influencing recharge and contaminant transport (Gaaloul et al., 2014; Chenini et al., 2015; Lachaal et al., 2016). Hydrochemical studies indicate **increasing salinity and nitrate contamination** in shallow, central areas, likely due to irrigation return flows and anthropogenic inputs (Kammoun et al., 2018a; Slama & Sebei, 2020).

RESULTS & DISCUSSION

- **Central Zone:** Shallow, unconfined aquifers with medium-permeability sediments → **High vulnerability (GOD ≈ 0.8–0.9)**
 - **Eastern & Southwestern Zones:** Deep, confined aquifers → **Very low vulnerability (GOD ≈ 0.4)**
 - **Western & Northern Zones:** Intermediate depths and poorly consolidated sediments → **Moderate vulnerability (GOD ≈ 0.5–0.7)**
- Implications:**
- High-risk areas coincide with zones of increasing salinity and nitrate contamination, linked to irrigation return flows and anthropogenic inputs.
 - Vulnerability patterns reflect lithology and depth variations across the aquifer system.

Parameters were assigned based on hydrogeological conditions and regional studies (Table 1).

Table 1. Parameters considered for the application of GOD method to Grombalia aquifer.

Parameter	Definition	East & SW (deep/confined)	Central (shallow/unconfined)	West/North (moderate)
G (Groundwater occurrence)	Confined vs. unconfined	0.2	1	1
O (Overlying lithology)	Clay → low perm.; sandy → medium perm.	0.5	0.7	0.6
D (Depth to water table)	Depth in m	0.5 (>50 m)	0.8–0.9 (<20 m)	0.7 (20–35 m)
GOD	Average of G, O, D	0.4	0.8	0.77

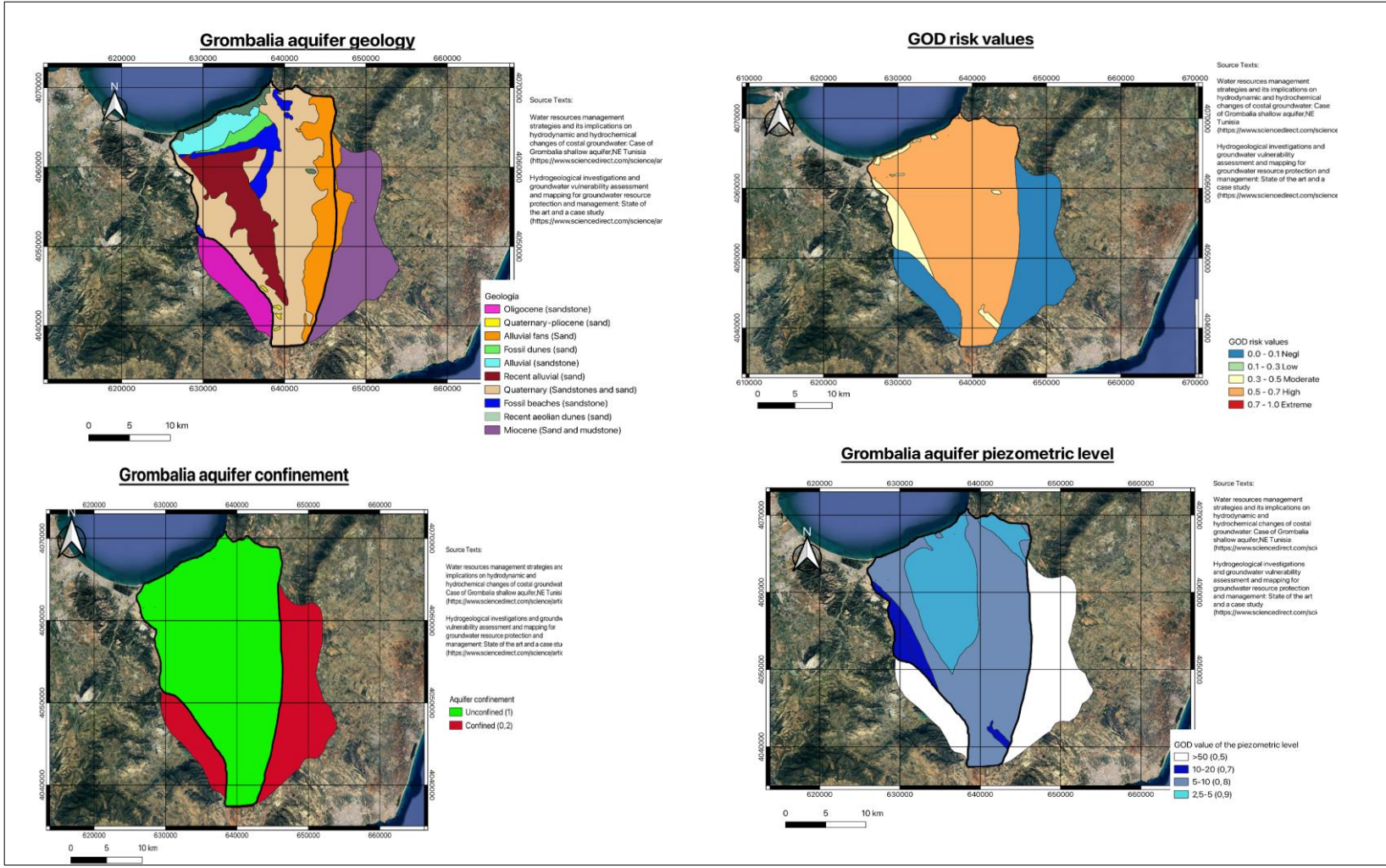


Figure 3. Geology, risk values, aquifer confinement and aquifer piezometric levels obtained.

Interpretation (Figure 3):

- Shallow, unconfined areas (central sector) show highest values (0.8-0.9), this is high vulnerability.
- Deep, confined areas (east and southwest) have GOD 0.4 or lower, this means very low vulnerability.
- Intermediate zones (west and north) show moderate vulnerability (0.5-0.7).

Results:

The GOD index was calculated using GIS-based algebraic mapping in QGIS, applying the average of the three parameters (G+O+D)/3. Vulnerability zonation results are as follows (Table 2):

- **Very low vulnerability (0.0-0.1):** Areas with water table depths below 50 m.
- **Moderate vulnerability (0.3-0.5):** West and north zones with poorly consolidated sediments.
- **High vulnerability (0.5-0.7):** Central aquifer region, with shallow water table and medium permeability materials.

Table 2. Vulnerability classes obtained from GOD application to Grombalia aquifer.

Vulnerability Class	GOD Index	Hydrogeological Characteristics	Management Implications
Very Low	0.0–0.4	Deep, confined aquifers; low-permeability cover	Limited monitoring; low risk from surface contamination
Moderate	0.4–0.7	Intermediate depths; poorly consolidated sediments	Targeted monitoring; precaution in land use planning
High	0.7–1.0	Shallow, unconfined aquifers; medium permeability	Priority protection zones; strict pollution control; recharge management

- High-risk central areas require immediate protection measures, such as controlled fertilizer application, artificial recharge, and monitoring wells.
- Moderate-risk zones benefit from seasonal monitoring, especially during drought periods or intensive irrigation.
- Low-risk sectors need baseline water quality surveillance, with attention to potential contamination sources.

CONCLUSION

The GOD method effectively identifies intrinsic vulnerability in heterogeneous aquifer systems. Results highlight the need for strict pollution control in shallow, unconfined zones and targeted monitoring in moderate-risk areas. Deep confined aquifers remain naturally protected but require surveillance against potential deep percolation contamination.

REFERENCES AND ACKNOWLEDGEMENTS

- Combine GOD with hydrochemical and isotopic data for validation.
 - Develop integrated vulnerability-risk models incorporating land use and climate scenarios.
 - Implement adaptive monitoring strategies for semi-arid coastal aquifers.
- References:**
- Gaaloul et al. (2014); Chenini et al. (2015); Lachaal et al. (2016). *Hydrogeology of Grombalia aquifer*.
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