A GIS-based SINTACS model for assessing intrinsic groundwater vulnerability of the Alton Kopri basin, Kirkuk governorate northeast of Iraq.

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Abstract. The Alton Kopri Basin is an important and significant water basin in Kirkuk governorate where most of the area demand like drinking, agricultural, grazing, and industrial are depending on it. The basin consist of two main aquifers the upper aquifer formed by Quaternary deposits and the lower confined aquifer formed by Muqdadyi and Bai Hassan formations, the hydrological conditions for the lower aquifer changed laterally from confined to semi-confined down to unconfined from the center of the basin to northeast of the area. Flow direction from northeast to northwest coincident with topographic elevation trend. The annual groundwater recharge estimated by chloride mass balance method is (124 mm). It is important to assess the potential of ground water for pollution. For this purpose intrinsic vulnerability was assessed using SINTACS model with the aid of geographic information system (GIS) techniques. The final results show that two zones moderate and high vulnerability classes dominant the study area in the case of normal scenario occupied area are 423 km² and 649 km² respectively, the relevant scenarios represents with two categories, moderate category occupy 491 km² and high category occupy 549 km². Three zones low, moderate, and high characterizes the nitrate scenario with 77 km², 523 km², and 440 km² respectively, the SINTACS is the most subjective because of the wide range of the rating of some parameters. The high vulnerability zone exists in the most part of the basin center, where the unconfined upper aquifers exist. Accordingly, the impact of aquifer media, soil texture, and vadose zone is the most effective parameters in SINTACS model.

Keywords: Iraq, Kirkuk, Alton Kopry, Groundwater, Vulnerability, SINTACS.

Introduction

The Alton Kopri Basin is an important and significant water basin in Kirkuk governorate. It supplies drinking water for over 95% of the rural population and over 50% of the urban population in this region. Protection of the groundwater in the Alton Kopri Basin has become a significant concern. Generally, the groundwater resources assessment is a key for integrated water resources management. Correct and detailed assessment of groundwater water resources is of great importance to plan, design, realize and manage any water resources development project. The results of the assessment are the basis for any decision making process, since they can lead to large investments and serious consequences on the environment (Al Mallah &Al Qurnawi 2018). Groundwater resources assessment...
consists of determining their quantity, quality, and availability for sustainable development and coherent management (WHO 2004). Groundwater quality management must be one of the first tasks that should consider in groundwater management, especially for the fresh (drinking) water aquifers supplies. To effectively and properly protect groundwater, it is crucial being able to identify areas where groundwater may be most vulnerable to contamination and translate this information into vulnerability maps that can be used by water-resources manager users, to prevent or minimize harmful impacts on groundwater quality (Arthur et al.2007). Various methods, based on different approaches and using different input parameters have been developed to perform groundwater vulnerability assessment. However, vulnerability can be considered effective tools to be used in environmental planning and management. In fact, a groundwater vulnerability map considered one of the promising tools in groundwater management and the first step to evaluate and determine delineation protection zones (Sorichetta 2010).

The Alton Kopri basin is one of the freshest aquifer in the north of Iraq which is mainly used for human demand in drinking, domestic, agricultural, grazing and a little percentage in industrial demand. Because of its important resource it should be preserve from different contaminants and the first step is to fix the high naturally vulnerability areas in the basin to give it more attention in protection. The aim of this study is to assess the intrinsic vulnerability of the Alton Kopri basin by using an overlay and index SINIAC approach in framework of geographic information system (GIS). This considered as a first step for efficient manage this very important aquifer.

**The study area:**

The study area located in north of Iraq, northeast of Kirkuk City, located between latitudes N35o 30’ – 35o 50’ and longitudes E44o 010’ – 44o 35’ and occupies an area of (1040.8 km2), the region elevation ranges between 220- 800m (a.s.l) figure (1). Bordered by Kalkalan Mountain from Northeast and Kanydomlan Mountain in Southwest. The Lesser Zab River bounded the basin from the northeast. From the southeast the basin bounded with Khassa Chai River by topographic divide figure (2).

The lithostratigraphic sequence of the study area represent by Injana, Muqdayi and Bai Hassan Formations belong to the Late Miocene-Pliocene Epoch the last one in Tertiary sediment period table (1), in addition to a recent deposit sediment belong to Quaternary period throw Pleistocene- Holocene Epoch which called Quaternary sediment also (Parson, 1955; Buday, 1980).

Tectonically the basin area is a part of the foothill zone in the folded area of unstable shelf in Chemchemal –Butmah subzone, northern Iraq. This area is characterized by some long and high folds trending anticline with complex submerge concave in two directions northwest –southeast which the valleys and flat plain limited inside between folds figure (3) (Buday and Jassim, 1987).

The local weather in the study area is hot –dry in summer and cold –wet in winter. The maximum mean temperature which has been recorded was (46.6 °C) in July 2000 and the minimum mean temperature was (1.6 °C) in January 1984. The maximum monthly averages rainfall are 288mm in January and 1.6mm in June throw the period (1971-2013). Potential evapotranspiration is round from 37.2mm to 257.3mm in January and July respectively. The Muqdayi and Bai Hassan Formations are the lithohydrological formations in the studied basin with a large thickness, as well as Quaternary deposits in the centre of the basin characterize them. Thicknesses of these units are different between the centre to the edge of the basin. The reduction in thickness is toward the edge basin (Haddad et al, 1971). The lithological composition of these formations vary between sandstone mixture of gravel with sand and clay in Muqdayi and Bai Hassan Formations and gravel with sand, clay and silt in Quaternary deposits (Haddad et al, 1971). The main source of recharge in the study area is rainfall. The percolated rainfall water moves through the gravel layer, conglomerate and in the sandstone layer in Muqdayi and Bai Hassan Formations( Al Abadi et al, 2016).
Figure (1) Topography of the study area derived from US DEMs.

Figure (2) the study area of Alton Copry Basin.
**Figure (3)** The structural setting to the study area (modified after IGS 1996).

**Table (1)** Stratigraphic succession for geological formations of Alton Kopy basin (Haddad et al., 1971)

| Era     | Period   | Epoch | Sub-epoch | Formation               | Environment | thickness |
|---------|----------|-------|-----------|-------------------------|-------------|-----------|
| Cenozoic| Quaternary| Holocene|           | Wade fill and river terraces | Continental | 10        |
|        |          | Pleistocene|           | Younger and older alluvium | Continental | 100       |
| Tertiary| Pliocene | Late      |           | Bai Hassan              | Continental | 1000-3000 |
|         | Miocene  | Upper     |           | Muqdadyi                | Sub-Continental | 2000     |
|         |          |           |           | Injana                  |             |           |

In the western part of the basin, the water flows toward northeast of the basin to center of the basin and then to the discharge area toward the Little Zab River (Al-Sudani, 1998). The upper aquifer is unconfined, and it is limited by the upper layer of Quaternary deposit figure (4). The Muqdadyi and Bai Hassan Formations are the water bearing formations in the studied basin. The lower aquifer is confined to semi-confined in Bai Hassan Formation (General Directorate of water well drilling, 2000; Haddad, 1971). Aquifer thickness in the middle basin is about (100m), while this thickness decreases to less than (50m) on the edge of the basin (Al-Aney, 1983).
Groundwater is mostly deep, the wells are deeper toward the highest topographical areas, and they extend from 25m to 180m. Table (2) shows the information of the study area wells.

| UTM coordinate | Easting | Northing | Well No. | Altitude (m) (a.s.l.) | Well depth (m) | Static water depth (m) | Total head a.s.l (m) | Aquifer thickness (m) |
|----------------|---------|----------|----------|-----------------------|----------------|------------------------|---------------------|----------------------|
| 442815         | 3936963 | w1       | 408      | 180                   | 14             | 394                    | 147                 |                      |
| 443219         | 3941089 | w2       | 405      | 122                   | 31.08          | 374                    | 82                  |                      |
| 441940         | 3953298 | w3       | 413      | 90                    | 13.56          | 400                    | 72                  |                      |
| 436612         | 3953088 | w4       | 351      | 100                   | 47             | 304                    | 46                  |                      |
| 439317         | 3940838 | w5       | 374      | 100                   | 24.3           | 350                    | 57                  |                      |
| 436742         | 3943197 | w6       | 364      | 50                    | 24.7           | 340                    | -                   |                      |
| 431236         | 3946750 | w7       | 337      | 100                   | 40             | 297                    | 43                  |                      |
| 424462         | 3951489 | w8       | 325      | 115                   | 72             | 253                    | 39                  |                      |
| 425314         | 3957151 | w9       | 299      | 112                   | 50             | 249                    | 62                  |                      |
| 446934         | 3943870 | w10      | 302      | 72                    | 23             | 408                    | 49                  |                      |
| 448724         | 3935911 | w11      | 495      | 170                   | 66             | 429                    | 104                 |                      |
| 453022         | 3934655 | w12      | 462      | 25                    | 10             | 452                    | -                   |                      |
| 453267         | 3942941 | w13      | 475      | 130                   | 8.5            | 467                    | 121.5               |                      |
| 445277         | 3948471 | w14      | 434      | 180                   | 24             | 410                    | 156                 |                      |
| 442713         | 3952430 | w15      | 431      | 130                   | 26             | 405                    | 104                 |                      |
| 440817         | 3950748 | w16      | 394      | 120                   | 56             | 338                    | 44                  |                      |
| 435812         | 3946716 | w17      | 335      | 93                    | 20             | 315                    | 74                  |                      |
| 434243         | 3952089 | w18      | 318      | 130                   | 18.2           | 300                    | 81                  |                      |
| 436351         | 3951704 | w19      | 335      | 110                   | 25.08          | 310                    | 30                  |                      |
| 431197         | 3957904 | w20      | 323      | 85                    | -              | -                      | -                   | 54                   |
| 440357         | 3964462 | w21      | 324      | 120                   | 17.5           | 306.5                  | 83                  |                      |
| 428042         | 3959100 | w22      | 292      | 70                    | 40             | 252                    | 30                  |                      |
| 425929         | 3961552 | w23      | 276      | 100                   | -              | 276                    | -                   |                      |
| 449236         | 3955040 | w24      | 586      | 150                   | 72             | 514                    | 78                  |                      |
| 445588         | 3958297 | w25      | 567      | 125                   | 37.3           | 530.7                  | 87.7                |                      |
Ground water vulnerability assessment using SINTACS

The SINTACS method was developed by (Civita and De Maio, 1997) to assess the intrinsic vulnerability of ground water. To assess the ground water vulnerability for the study area, SINTACS model was chosen for different considerations, these include: Its suitability for application in arid and semi – arid regions, and in Mediterranean regions (Civita, 1990). Its low cost, depending on available datasets, and dimensionless and non-measurable properties that depend on the aquifer characteristics as well as the characteristics of geological and hydrological environment (Civita and De Maio, 1997). Each parameter is giving a score, ranging from 1 to 10 based on their relative importance to the vulnerability mapping. The weight are assigned from 1 to 5, the weight of each variable will be different depending on the hydrological scenario. Five hydrological scenarios have been suggested, Table (3) shows the five scenarios with their relevant weights. A schematic flowchart for the assessment process of groundwater vulnerability using SINTACS model shows in figure (5).

Table (3) Scenario and weights of SINTACS parameter (Civita and De Maio, 1997).

| Parameter                                  | S | I | N | T | A | C | S |
|--------------------------------------------|---|---|---|---|---|---|---|
| Normal impact scenario                     | 5 | 4 | 5 | 3 | 3 | 3 | 3 |
| Relevant impact scenario                   | 5 | 5 | 4 | 5 | 3 | 2 | 2 |
| Drainage from surficial network scenario   | 4 | 4 | 2 | 5 | 5 | 2 | 2 |
| Karstic impact scenario                    | 2 | 5 | 1 | 3 | 5 | 5 | 5 |
| Fissuring scenario                         | 3 | 3 | 4 | 4 | 5 | 4 | 4 |
| Nitrates                                   | 5 | 5 | 4 | 5 | 2 | 2 | 3 |

By multiplying each rated parameter with their relative weight according to the specific scenario, the vulnerability index of SINTACS model can be calculated for each grid element using the following equation: (Civita and De Maio, 1997).

\[ I_{\text{SINTACS}} = \sum_{i=1}^{7} P_i \ast W_i \]  

(1)
Where:

$I_{SINTACS}$ is vulnerability index

$P_i$ is the rating of each parameter

$W_i$ is the weight of the chosen hydrological scenario.

The index indicates the potential contamination that may occur in the aquifer. $I_{SINTACS}$ values ranged from a minimum value of 26 to a maximum value 260. The vulnerability index classes ranges are shown in table (4).

| Vulnerability classes | Ranges $I_{SINTACS}$ |
|-----------------------|----------------------|
| Very low              | 26 – 80              |
| Low                   | 90 – 105             |
| Medium                | 110 – 140            |
| High                  | 150 – 186            |
| Very high             | 190 – 210            |
| Extremely high        | 220 – 260            |

To apply the SINTACS method on the study area, the base information and data of the area should be provide and prepared for the each seven thematic maps. The data were gathered from different sources such as field survey, geological and meteorological data, a digital elevation model DEM, archival database from Bagdad and Kirkuk Ground Water Directorate, and published researches. Geographic Information System ArcGIS 10.3 software was used to compile the geospatial data, to compute the SINTACS index, and to generate the final vulnerability maps. The different data and maps are converted into UTM system zone 38N. A model grid over the aquifer was then overlaid and assigned SINTACS rating to the grid cell for each of the seven hydrogeological factors. The raster grid of cell size 10 m (x, y) forming 3765 and 5232 columns and rows, respectively, is used. The aquifer vulnerability method calculated after merging the database information of the upper aquifer with lower aquifer. The SINTACS thematic layers preparation is as follows:

1. Depth to groundwater $S_D$

Depth to water table is the distance between the surface and the water table. This distance was obtained from the well logs, hydrological reports, and (Al-Sudani, 1998) thesis. In the hydrological reports of Ground Water Directorate, some information of the selected wells are absent or missing because not all the wells registered from the concerned directorate. To create the thematic map of the groundwater table depth, it is necessary to make interpolations between the well locations by using a kriging method and then reclassified into five classes using reclassify command in spatial analyst with regard to rating system. Table (5) summarized the depth to groundwater rating and weighting values after (Civita and De Maio, 1997) also rating and weighting values for the study area. Figure (6) illustrate depth to water rating and ranges in study area.

| Depth to water (m) | Rating $S_r$ | Depth to water (m) in study area | Rating $S_r$ in study area |
|--------------------|--------------|---------------------------------|---------------------------|
| 0 – 1              | 10           | 8-10                            | 6                         |
| 1 – 4              | 9            | 10-20                           | 5                         |
| 4 – 6              | 8            | >20                             | 4                         |
| 6 – 8              | 7            |                                 |                           |
| 8 – 10             | 6            |                                 |                           |
| 10 – 20            | 5            |                                 |                           |
| >20                | 4            |                                 |                           |
2. Effective infiltration (net recharge I):

Infiltration is the movement of water from the surface through the soil as distinguished percolation. The infiltration is equal to the net recharge (Pathak et al., 2009) which is computed by the mass chloride balance model for the all study area, it was 124 mm, according to table (6) the rated value assigned 5 for the net recharge. Figure (7) shows net recharge rating for the study area.

| Active recharge (mm/year) | Infiltration range | Rating I |
|---------------------------|-------------------|----------|
| 250 – 325                 |                   | 9        |
| 175 – 250                 |                   | 8        |
| 150 – 175                 |                   | 7        |
| 125 – 150                 |                   | 6        |
| 125 – 100                 |                   | 5        |
| 75 – 100                  |                   | 4        |
| 60 – 75                   |                   | 3        |
| 50 – 60                   |                   | 2        |
| <50                       |                   | 1        |

Figure (6) Depth to groundwater rating.
3. Unsaturated zone (N):

The unsaturated zone is the second defense layer of the hydrological system below the soil horizon and above the piezometric surface (Civita and De Maio, 2004). The main constituents of the unsaturated material according to table (7) are sandstone and conglomerate (Al-Abadi et al, 2016). The area is divided into two areas, and the rated values assigned at (7, 5) as shown in figure (8).

| Unsaturated zone attenuation                  | Rating $N_r$ |
|----------------------------------------------|--------------|
| Coarse alluvial deposits                     | 6 – 9        |
| Karstified limestone                         | 8 – 10       |
| Fractured limestone                          | 4 – 8        |
| Fissured dolomite                            | 2 – 5        |
| Medium- fine alluvial deposits               | 3 – 6        |
| Sand complex                                 | 4 – 7        |
| Sandstone, conglomerate                      | 5 – 8        |
| Turbidic sequences                           | 2 – 5        |
| Fissured volcanic rocks                      | 5 – 10       |
| Marl, clay stone                             | 1 – 3        |
| Clay, silt, peat                             | 1 – 2        |
| Pyro-clastic rock                            | 2 – 5        |
| Fissured metamorphic rocks                   | 2 – 6        |
4. Soil texture (overburden attenuation capacity $T$):

The soil texture characteristics are related to the amount of recharge that can infiltrate into the ground and hence indicate the potential of contaminants to move vertically into the unsaturated zone (Civita and De Maio, 2000). The presence of fine texture materials such as silt and clays relatively decrease soil permeability and restrict contaminant migration (Al-Amosh et al., 2010). Figure (9) shows the soil texture thematic map of the study area the rating of soil texture was performed based on values suggested by (Civita and De Maio, 1997) as listed in table (8) for each hydrological soil group A, B, and C which rated fixed to 8, 6, and 5, respectively.

Table (8) Rating scheme for different type of soil texture $T$ (Civita and De Maio, 1997).

| Soil texture type      | Rating $T_r$ |
|-----------------------|--------------|
| Clay                  | 1 – 1.5      |
| Silty – clay          | 1.5 – 2      |
| Clay loam             | 2 – 3        |
| Silty clay loam       | 3 – 4        |
| Silt loam             | 3.5 – 4      |
| Loam                  | 4 – 5        |
| Sandy clay loam       | 4.5 – 5      |
| Sandy loam            | 5.5 – 6      |
| Sandy clay            | 6.3 – 7      |
| Peat                  | 7.5 – 8      |
| Sandy                 | 8 – 8.5      |
| Clean sand            | 9 – 9.5      |
| Clean gravel          | 9.5 – 10     |
| Thin or absent        | 10           |
Soil texture rating.

5. Aquifer type (media A):

In the study area, information about the aquifer media characteristics was obtained from well logs and available hydrogeological information. The rating of this parameter was performed based on table (9) and figure (10) illustrate the suggested rating value to this parameter of the area.

Table (9) Rating scheme of different type of aquifer media A (Civita and De Maio, 1997).

| Aquifer type media                  | Rating A_r |
|-------------------------------------|------------|
| Coarse alluvial deposits            | 8 – 9      |
| Karstified limestone                | 9 – 10     |
| Fractured limestone                 | 6 – 9      |
| Fissured dolomite                   | 4 – 7      |
| Medium- fine alluvial deposits      | 6 – 8      |
| Sand complex                        | 7 – 9      |
| Sandstone, conglomerate             | 4 – 9      |
| Turbidic sequences                  | 5 – 8      |
| Fissured volcanic rocks             | 8 – 10     |
| Marl, clay stone                    | 1 – 3      |
| Clay, silt, peat                    | 1 – 3      |
| Pyro-clastic rock                   | 4 – 8      |
| Fissured metamorphic rocks          | 2 – 5      |
6. Hydraulic conductivity (C):

Hydraulic conductivity refers to the aquifer ability to transmit water. Aquifer with high hydraulic conductivity are considered high vulnerability to contaminations, high rating is assigned according to table (10) to SINTACS model, the resulted thematic map of rating are presented in figure (11).

Table (10) Rating scheme of hydraulic conductivity values (Civita and De Maio, 1997).

| Hydraulic conductivity (m/d) | Rating $C_r$ |
|-----------------------------|-------------|
| 432 – 864                   | 10          |
| 86.4 – 432                  | 9           |
| 43.2 – 86.4                 | 8           |
| 8.64 – 43.2                 | 7           |
| 4.32 – 8.64                 | 6           |
| 0.864 – 4.32                | 5           |
| 0.432 – 0.864               | 4           |
7. **Slope of topographic surface** (S):

The slope of topographic surface refers to slope variability of land surface. Topography slope helps to control the pollutant path that will run off or remain on the surface in one area long enough to infiltrate (Bazimenyera and Zhonghua, 2008). High rating is assigned to slight slope, the low slope areas tend to retain water for longer period of time, which allows a greater infiltration or recharge water and a greater potential for contaminant migration. The slopes of study area were scored based on values given in table (11). The spatial distribution of the rating score of this parameter is presented in figure (12).

**Table (11)** Rating scheme of slope values of topographic surfaces (Civita and De Maio, 1997).

| Slope % | Rating $S_r$ |
|---------|--------------|
| 0 – 2   | 10           |
| 3 – 4   | 9            |
| 5 – 6   | 8            |
| 7 – 9   | 7            |
| 10 – 12 | 6            |
| 13 – 15 | 5            |
| 16 – 18 | 4            |
| 19 – 21 | 3            |
| 22 – 25 | 2            |
| >26     | 1            |
Results and conclusion:

Vulnerability index map of SINTACS model:

After assign ratings for the seven thematic maps of SINTACS method, each thematic map was multiplied by their significant weight for two scenarios the Normal impact and Relevant impact, table (3). The third scenario represents the nitrate impact on the relative area which weighted according to table (3). To extract the SINTACS vulnerability index, the seven weighted thematic map summed by using raster calculator under special analyst command.

The first vulnerability index of normal scenario was between 109 to 166, which classified into two categories dependent on table (4) of vulnerability classes. These include moderate and high vulnerability as shown in figure (13). Moderate category occupied 423 km$^2$ about 41% from the study area while high category occupied 649 km$^2$ (59%) of the study area. The high vulnerability zone exists in the most part of the basin center, where the unconfined upper aquifers exist. Accordingly, the impact of aquifer media, soil texture, and vadose zone is the most effective parameters in SINTACS model.

The relative impact of the second scenario ranged between 110 to 159, which classified into two categories moderate and high vulnerability. The vulnerability index values of second scenario is closer to the ranged values of normal scenario, that depend on the weighted score for each scenario, table (4). The high intrinsic vulnerability zone is predominant the most area of the basin. The moderate category occupied 491 km$^2$ about 47% of the study area, while the high category occupied 549 km$^2$ about 53% of the study area. Figure (14) shows the intrinsic groundwater vulnerability classes to the second scenario.

In the second scenario, the moderate category increased by 6% than the normal scenario due to the relevant weight for soil texture and unsaturated zone which are more effective in areas with intense agriculture. A special scenario present for the areas with heavily intensive agriculture where the effective of nitrate is predominant. The thematic rating map of this scenario was multiplied by nitrate weight as shows in table (3).
In order to evaluate the validity of the SINTACS vulnerability map for nitrate scenario, a correlation was made between the vulnerability levels and nitrate concentration for the area. The distribution of nitrate concentration is shown in figure (14). The distribution of nitrate concentration is depending on chemical analysis of 25 water samples extracted for the aquifer in the study area. The nitrate concentrations varied from 11mg/l to 38mg/l, which are in the limits of drinking water standard level for groundwater recommended by WHO (1996).
The vulnerability index of nitrate scenario was classified into three categories as shown in figure (15). The nitrate scenario is taken into account to determine intrinsic vulnerability if the agricultural areas expanded in their future activities in which the NO$_3^-$ considering a contaminant constitute that effect water quality. The vulnerability zones distributed between low category which occupy 77km$^2$ about 8% of the study area, moderate category occupy 523km$^2$ about 50%, and high category occupy 440km$^2$ about 42% of the study area. The low category zone distributed in small area where the NO$_3^-$ concentrations low compared to other parts of the study area. These area located in the foothill zone in the barren land. No agricultural activities are observed in this area.

The high nitrate vulnerability zone is located in the central part of the basin where the agriculture activities dominant. The nitrate concentration is increased diagonally from south-west to north-east, and vertically to the north-west. The moderate zone occupy the remaining area.

Most of the selected wells of the study area (17 wells) are located in the high vulnerability zone which is corresponding to the distribution of nitrate concentrations in the area about. Figure (16) illustrate the distribution of wells in the vulnerability zones.

![Figure (14) Nitrate concentration distribution in study area.](image-url)
Figure (15) Groundwater vulnerability nitrate index SINTACS model.

Figure (16) Wells distribution in vulnerability zones.

Conclusions
SINTACS based GIS technique is used to investigate the groundwater vulnerability for the main aquifer in Alton Copry basin, the obtained results show that:

The SINTACS model is the most subjective method because of the wide range of the rating of some parameters. Vulnerability mapping with SINTACS seems very useful for land use management, they
can applied widely because of the large data used. The results of vulnerability assessment SINTACS model is likely to be of adequate use for vulnerability mapping in deep water depth aquifers. It is noted from the results of the SINTACS model for each normal and relevant scenarios that the area exposed to high vulnerability located in the center of the basin and in the Northwest of the study, that part which should be focused on the protection from exposure to future contamination, where the aquifer is unconfined, the results of vulnerability SINTACS nitrate scenario distribution is corresponding to the situation of vulnerability in normal and relevant scenarios. Therefore, priority should be given to protect and sustainable groundwater reserve from contamination, a protective measurement must take in consideration before the beginning of exploiting the aquifer for comprehensive human activities especially the agricultural activities in the area.

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