CRASTE-LF, ONU EHTP ABHSMD UM5 ISR FSR

Comparative study of the evaluation methods of aquifers' vulnerability to pollution in a porous environment with use the GIS tools.

With Application to the aquifer of Souss-Chtouka, Morocco

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CORUM CONFERENCE CENTER
43rd IAH congress

Plan

1. Objectives of the study
2. Approach of the study
3. Methods for the study
4. Presentation of the study area: Souss-Chtouka basin
5. Development of maps of vulnerability to pollution of the Souss-Chtouka aquifer
6. Comparative analysis of the used methods' results
7. Mapping of the risk to pollution of the Souss-Chtouka aquifer

Conclusion & Recommandations

Problematic

Population growth

Climate change

Intense agricultural activities

Urbanization

Industrial activities

Harmful to water resources

Protection of water resources to pollution

Characterization of groundwater's vulnerability to pollution

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Problematic

- Many of the methods (more than 20) of determination of groundwater's vulnerability to pollution have been developed in the world;

- These methods are more or less complex and more or less precise.

1. Objectives of the study

- Test of some methods of characterization of aquifers' vulnerability to pollution in porous environment;

- Recommendation of the most representative method for the characterization of aquifers' vulnerability to pollution in porous environment.

2. Approach of the study

1St step: Elaboration of the cards of vulnerability to pollution with the methods used (porous environment)

2Nd step: Comparison of the obtained results

3Rd step: Test of the obtained results'validity with the history of groundwater quality

4Th step: Choice of the most representative method for the characterization of the Souss-Chtouka aquifer's vulnerability to pollution

5Th step: Elaboration-of the map of the Souss-Chtouka aquifer's risk to pollution

3. Methods for the study

Presentation of the methods used for the study

- **DRASTIC**
- **DRASTIV**
- **SINTACS**
- **DRIST (Sinan, 2000)**
- **GOD**
- **Minnesota Level 2**

Parameter	Weight
[D] **D**epth of the water	5
[R] **R**echarge	4
[A] **A**quifer media	3
[S] **S**oil media	2
[T] Topography	1
[I] **I**mpact of the vadose zone	5
[C] **H**ydraulic conductivity	3

Calculation of the Index of DRASTIC Vulnerability :

$$IVD = DsDw + RsRw + AsAw + SsSw + TsTw + IsIw + CsCw$$

3. Methods for the study

Presentation of the methods used for the study

- DRASTIC
- DRASTIV
- SINTACS
- DRIST (Sinan, 2000)
- GOD
- Minnesota Level 2

✓ **Adjusted DRASTIC : replacement of C by Ve**

Parameter	Weight
[D] Depth of the water	5
[R] Recharge	4
[A] Aquifer media	3
[S] Soil media	2
[T] Topography	1
[I] Impact of the vadose zone	5
[V] Effective speed	3

$$Ve = \frac{K * i}{ne}$$

Calculation of the Index of DRASTIV Vulnerability :

IVDV = DsDw + RsRw + AsAw + SsSw + TsTw + IsIpw+ VsVw

With:

K = Hydraulic conductivity (m/s)

i = Hydraulic gradient

ne = Effective porosity

3. Methods for the study

Presentation of the methods used for the study

- DRASTIC
- DRASTIV
- SINTACS
- DRIST (Sinan, 2000)
- GOD
- Minnesota Level 2

Parameter	Score: Normal impact	Score: Severe impact
[S] Depth to water table	5	5
[I] Effective infiltration	4	5
[N] Unsaturated zone attenuation capacity	5	4
[T] Soil	4	5
[A] Aquifer Hydrogeologic features	3	3
[C] Hydraulic conductivity	3	2
[S] Topography	2	2

3. Methods for the study

Presentation of the methods used for the study

- DRASTIC
- DRASTIV
- SINTACS
- **DRIST (Sinan, 2000)**
  - a) Vertical Vulnerability
  - b) Sensitivity to pollution of an aquifer (Or Horizontal Vulnerability)
- GOD
- Minnesota Level 2

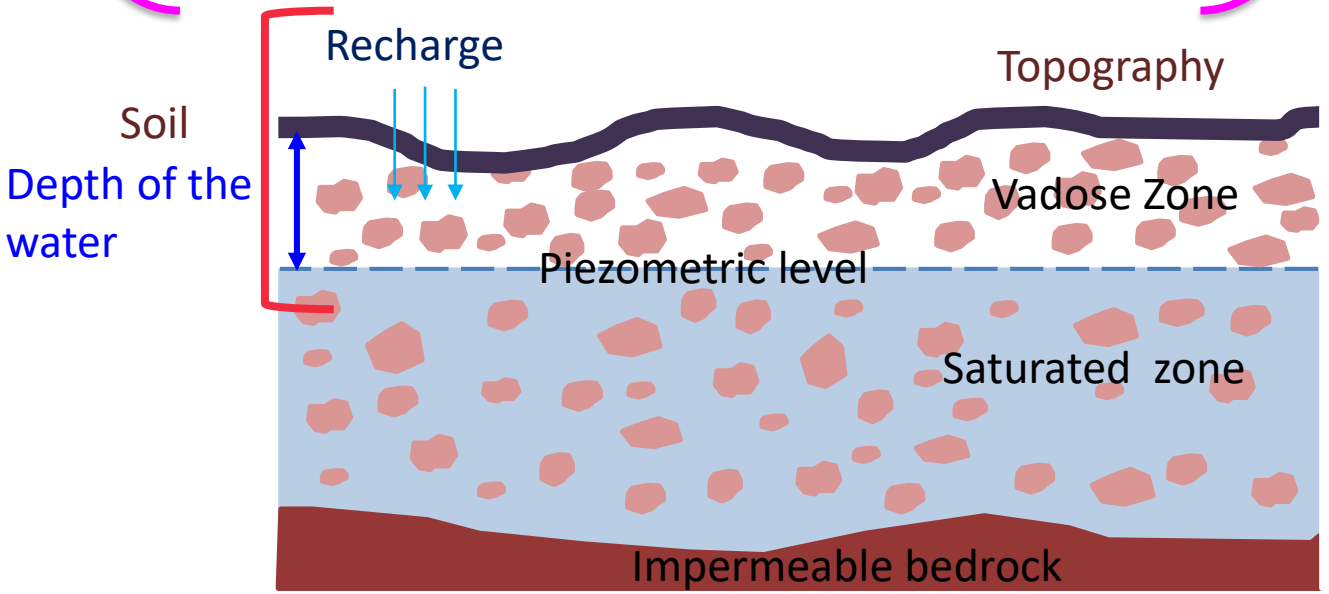
3. Methods for the study

Presentation of the methods used for the study

- DRASTIC
- DRASTIV
- SINTACS
- **DRIST (Sinan, 2000)**
- GOD
- Minnesota Level 2

a) Vertical Vulnerability

Parameter	Weight
[D] **Depth to water table**	**5**
[R] Efficient or net recharge	**4**
[I] Impact of the vadose zone	**5**
[S] Soil media	**2**
[T] Topography	**1**



3. Methods for the study

Presentation of the methods used for the study

- DRASTIC
- DRASTIV
- SINTACS
- **DRIST (Sinan, 2000)**
- GOD
- Minnesota Level 2

b) Sensitivity of groundwater to pollution

Parameter	Weight
Speed of groundwater	3
Water Quality	5
Productivity of aquifer	4

Calculation of the index of sensitivity with DRIST method

$$Is = (Qs \times Qw) + (Ps \times Pw) + (Ss \times Sw)$$

3. Methods for the study

Presentation of the methods used for the study

- DRASTIC
- DRASTIV
- SINTACS
- DRIST (Sinan, 2000)
- GOD
- Minnesota Level 2

Parameter
G : Type of aquifer
O : Lithology of the Aquifer
D : Depth of the water

Calculation of the index of GOD method

$$IG = I_G \times I_O \times I_D$$

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3. Methods for the study

Presentation of the methods used for the study

- DRASTIC
- DRASTIV
- SINTACS
- DRIST (Sinan, 2000)
- GOD
- Minnesota Level 2

Parameter
G : Hydraulic conductiviity
O : Lithology of the unsaturated zone
D : Thickness of the unsaturated zone

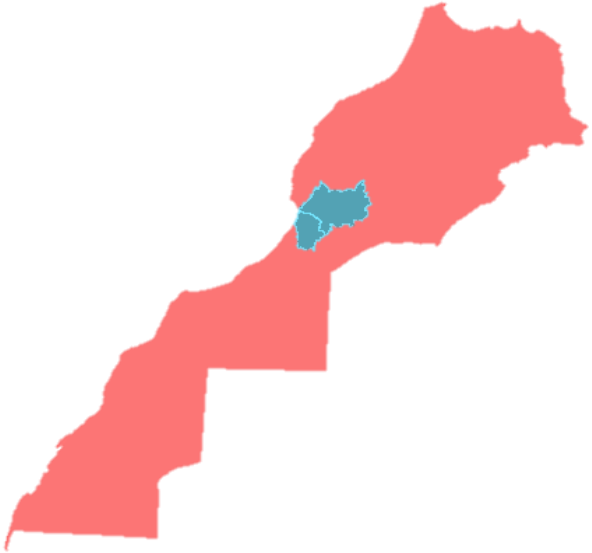
Degree of Vulnerability to pollution	Estimated journey time of vertical migration of the water table
Very high	From a few hours to a few months
High	From a few weeks to a few years
Moderate	From a few years to a few tens of years
Low	From a few tens of years to a century

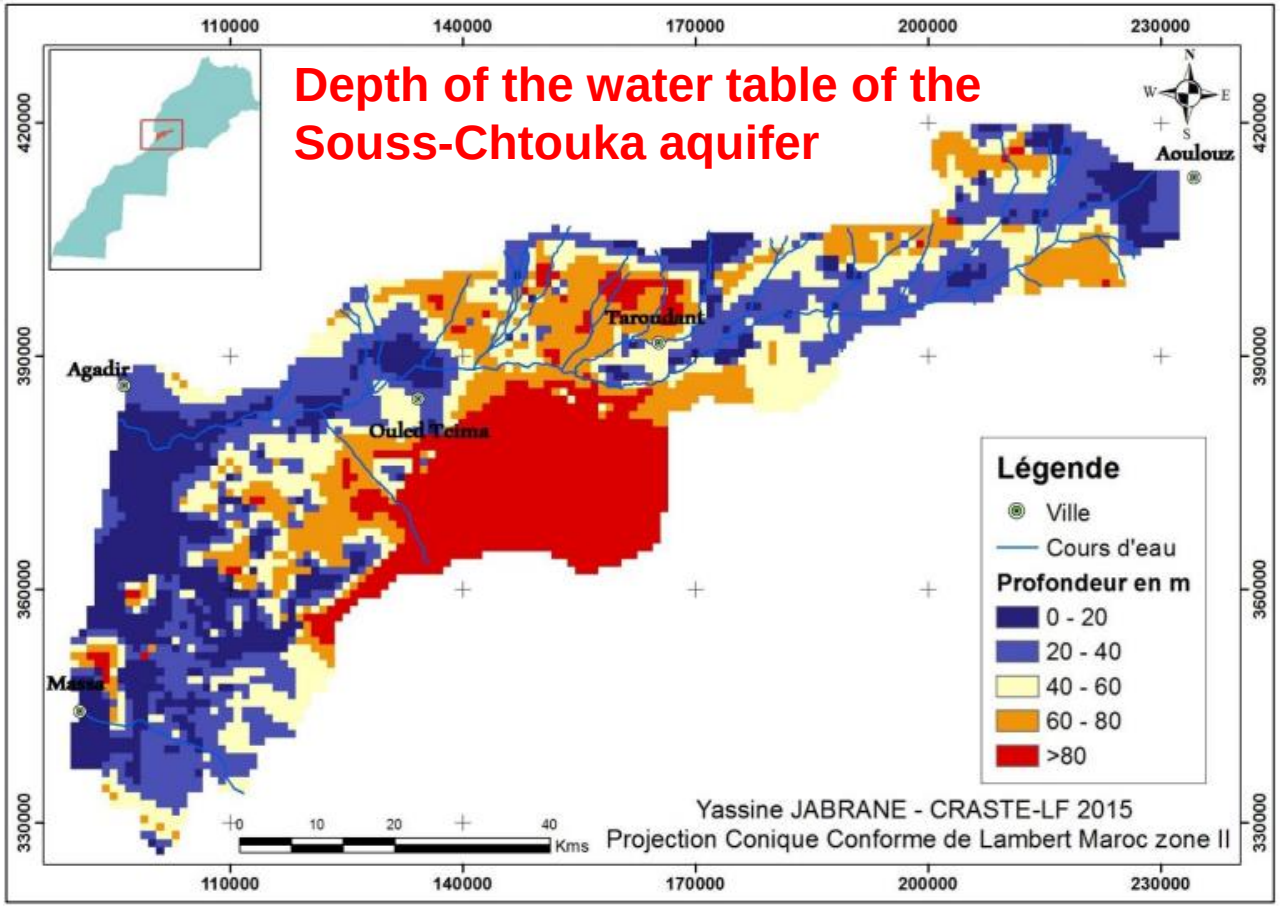
4. Presentation of the study area: Souss-Chtouka basin

- Watershed area of the Souss river (15.470 km²)
- The watershed of the Massa river (6.000 km²)

Population
2 382 565 hab

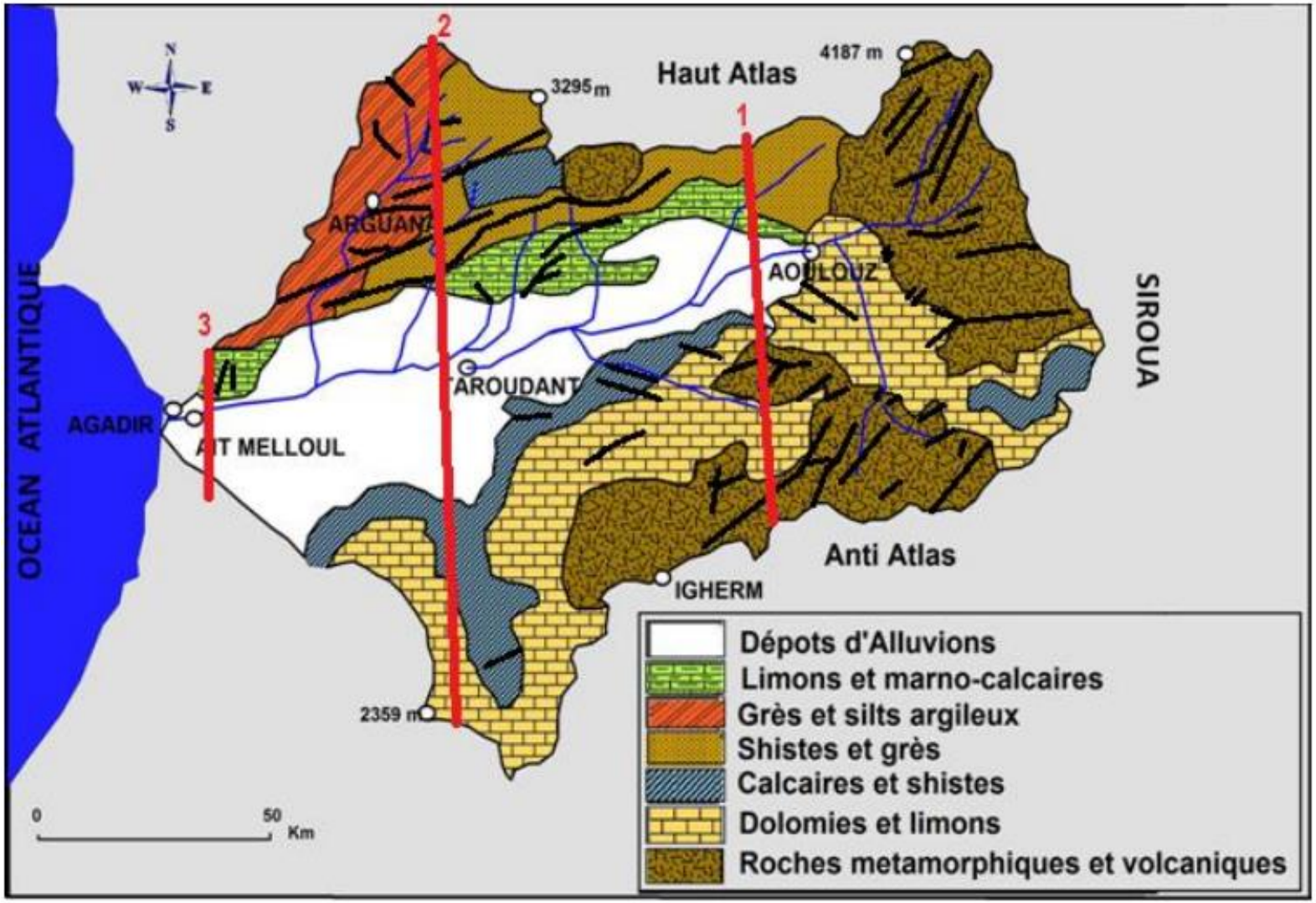
Activities:
- ✓Agriculture
- ✓Tourism
- ✓Industry





4. Presentation of the study: Souss-Chtouka basin

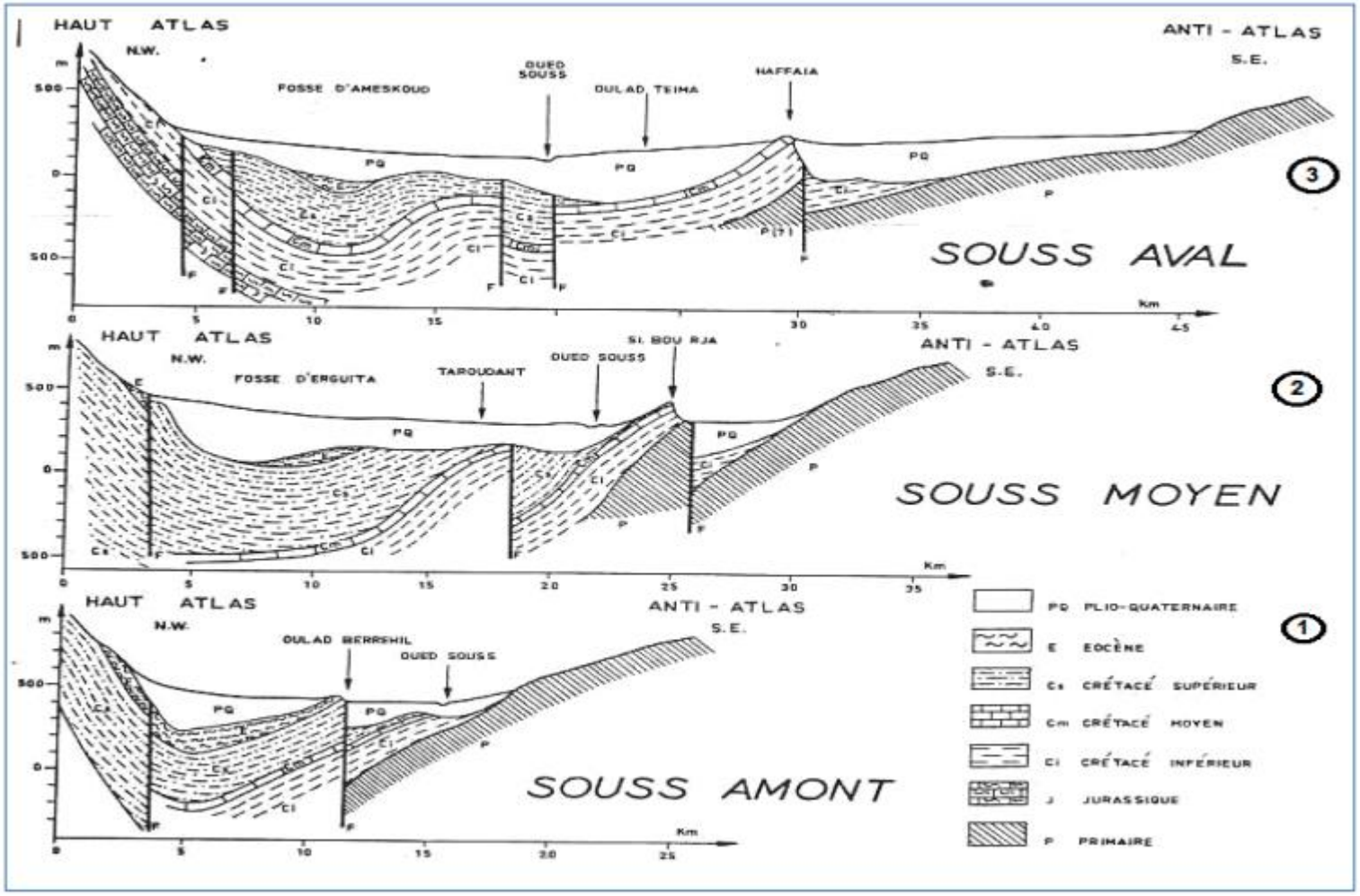
General geology of the Souss-Chtouka basin



(ABHSMD)

4. Presentation of the study area: Souss-Chtouka basin

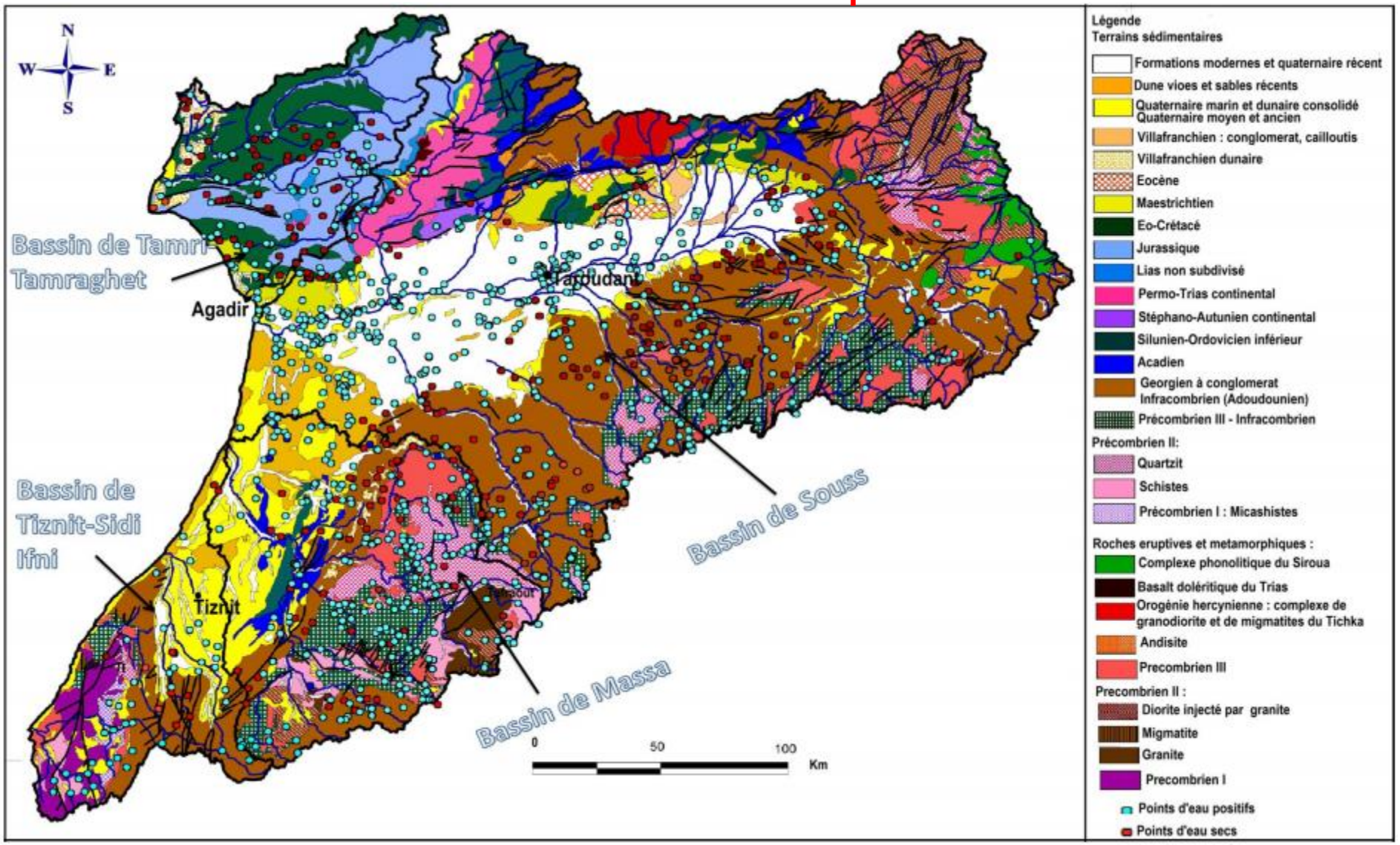
Geological cuts across the Souss-Chtouka basin



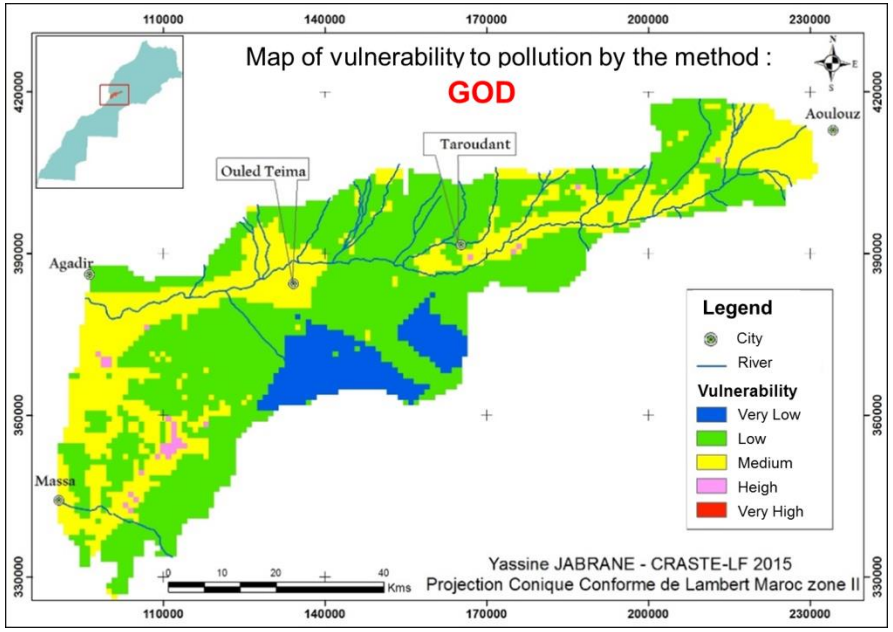
(Combe and El Hebil, 1972)

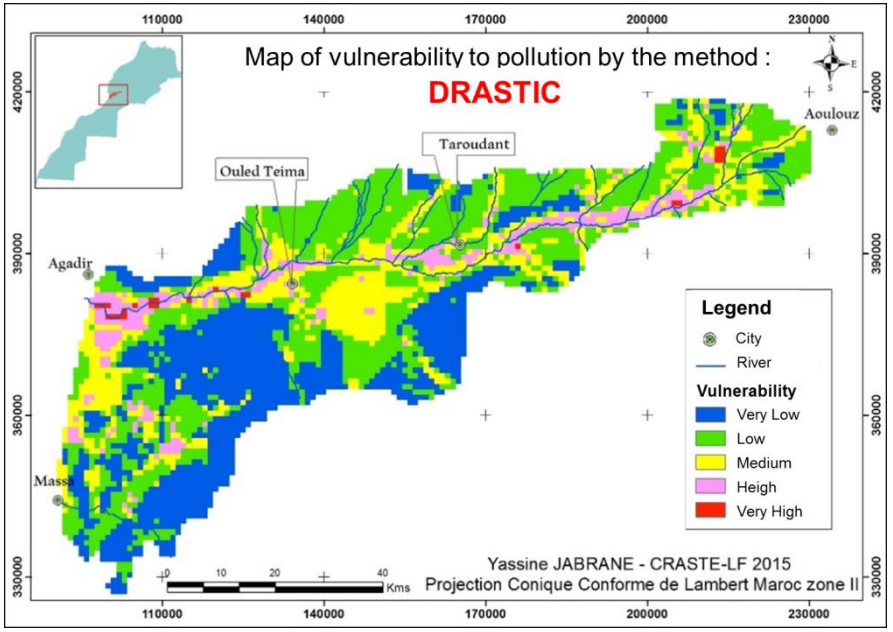
4. Presentation of the study area: Souss-Chtouka basin

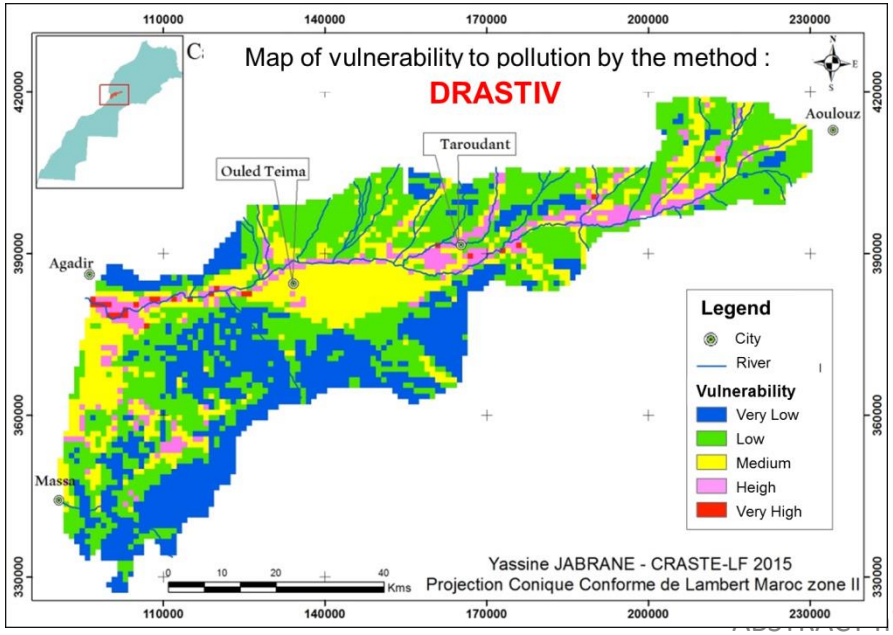
Distribution of the productivity of wells and drillings the Souss-Chtouka aquifer

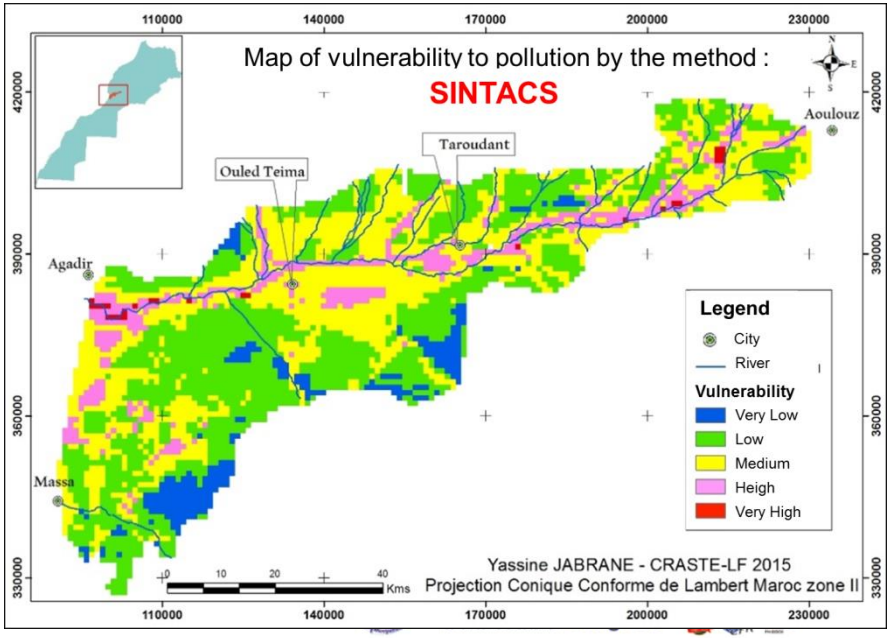


5. Development of maps of vulnerability to pollution of the Souss-Chtouka aquifer

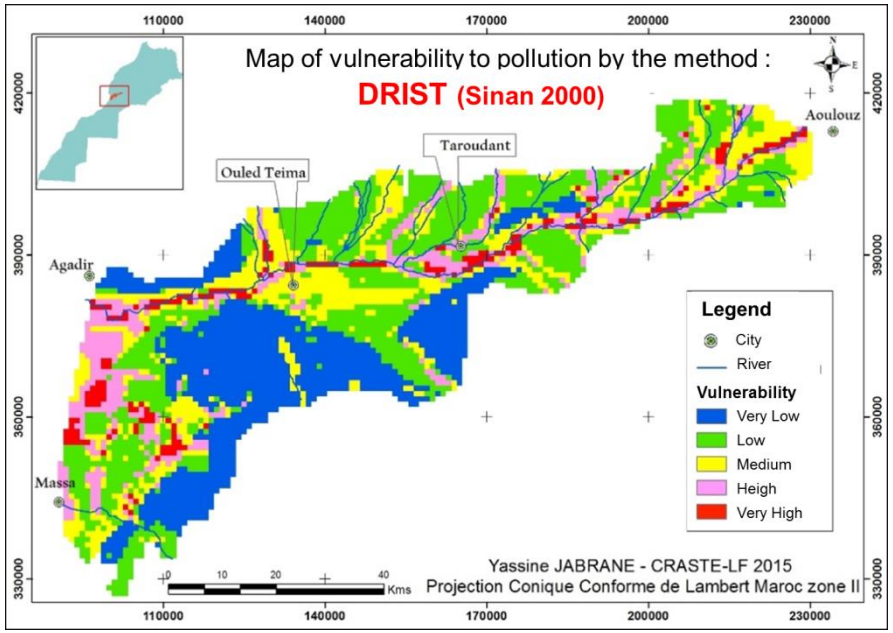


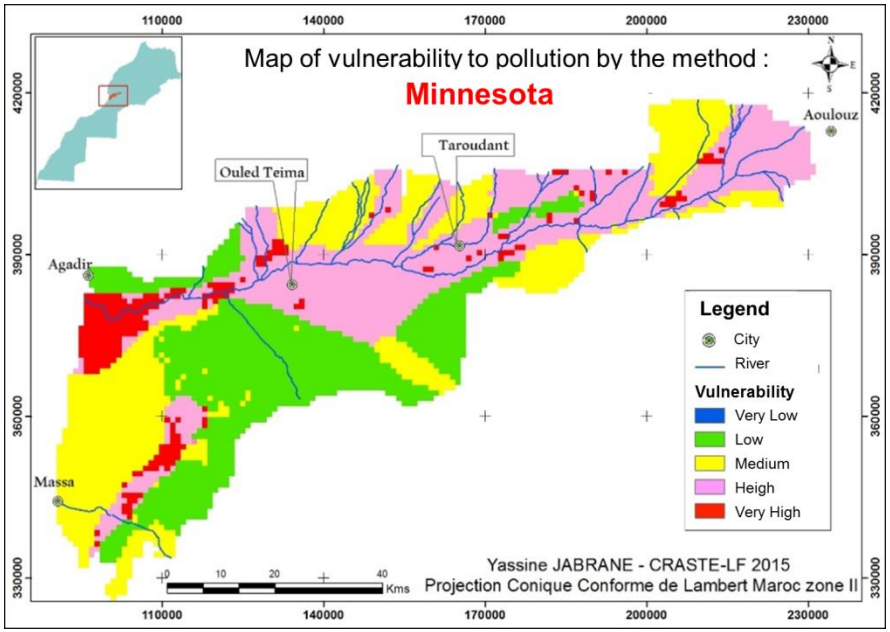


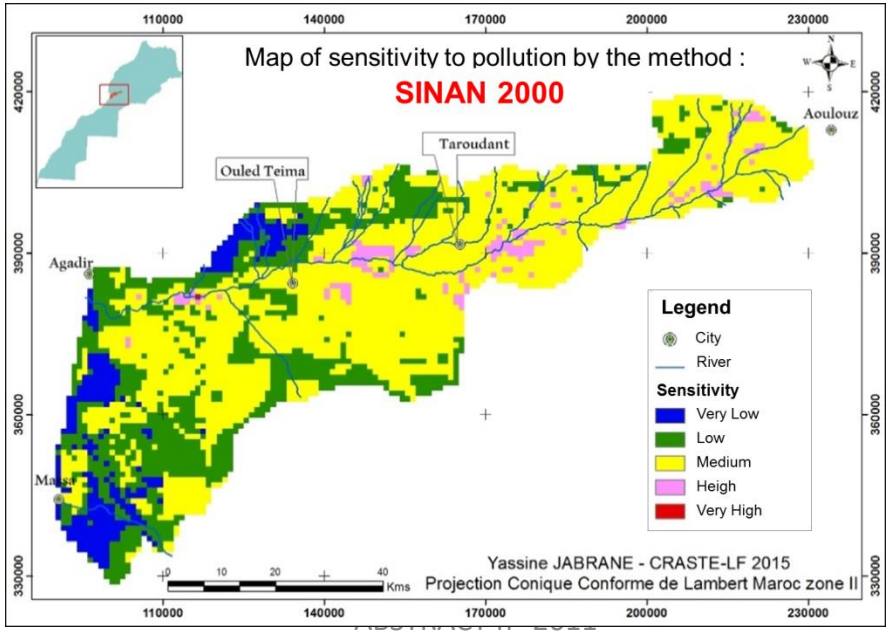




5. Development of maps of vulnerability to pollution of the Souss-Chtouka aquifer



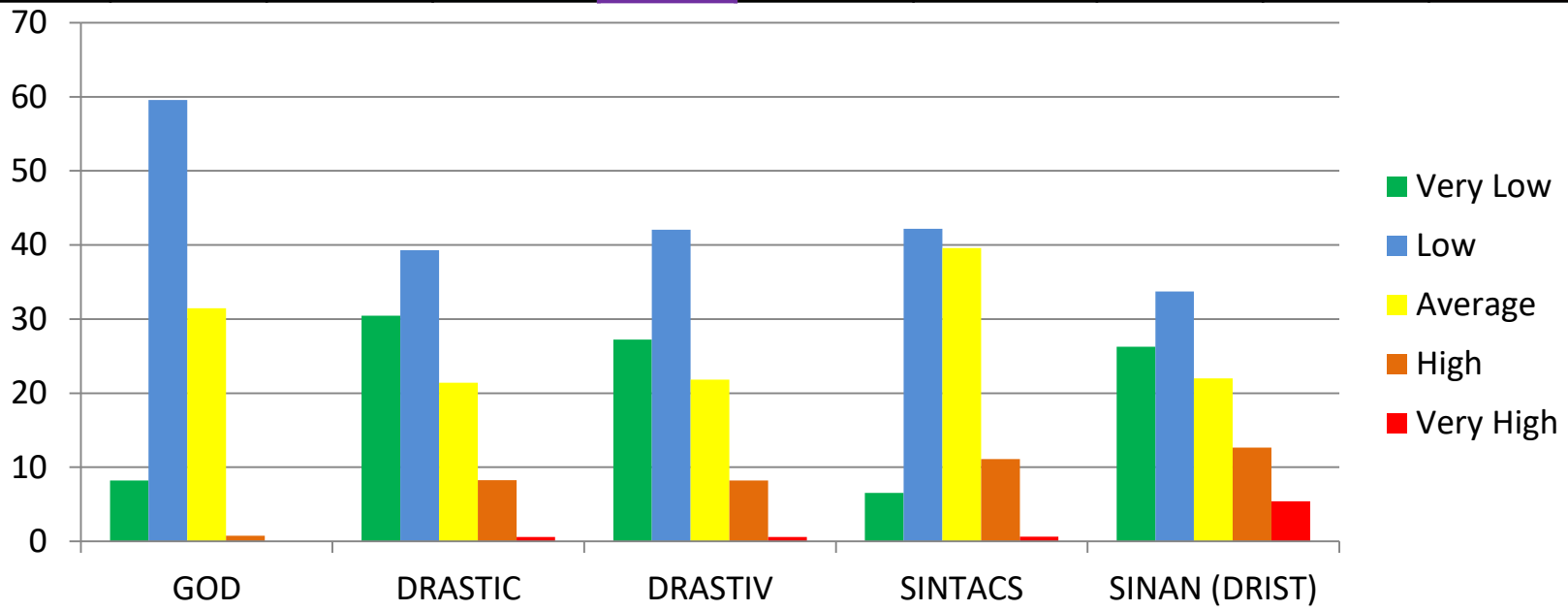




6. Comparative analysis of the used methods' results

6.1 Statistical comparison

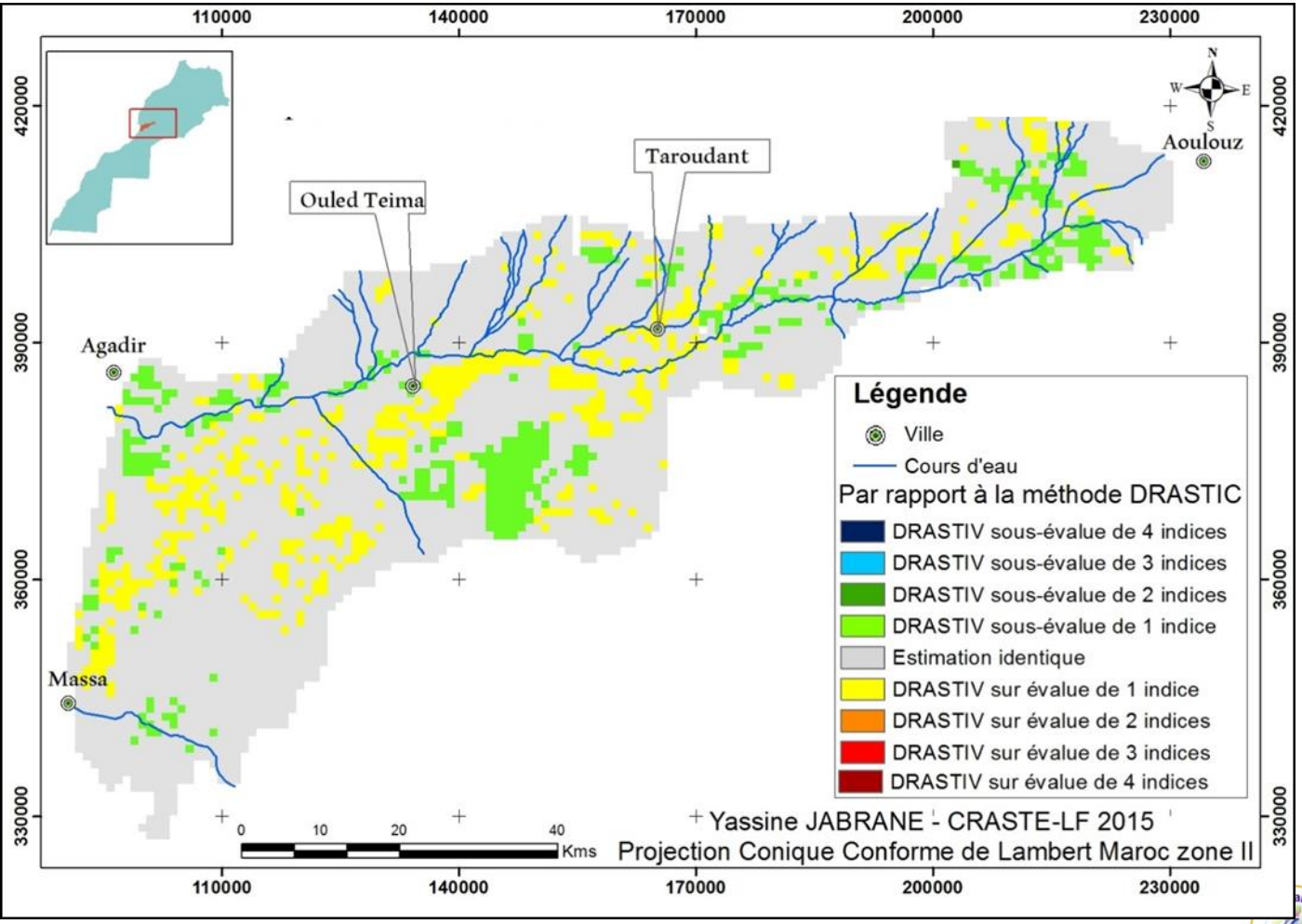
Method	Vulnerability to pollution									
	Very Low		Low		Average		High		Very High	
	Area	%	Area	%	Area	%	Area	%	Area	%
GOD	361	8,2	2622	59,59	1384	31,45	33	0,75	0	0
DRASTIC	1322	30,45	1706	39,29	929	21,4	359	8,27	26	0,6
DRASTIV	1180	27,25	1821	42,05	946	21,84	355	8,20	26	0,6
SINTACS	283	6,53	1827	42,17	1714	39,57	481	11,1	27	0,6
SINAN (DRIST)	1140	26,25	1465	33,73	955	21,99	549	12,64	234	5,4
Minnesota	-	-	1207	27,87	1328	30,66	1518	35,05	278	6,42

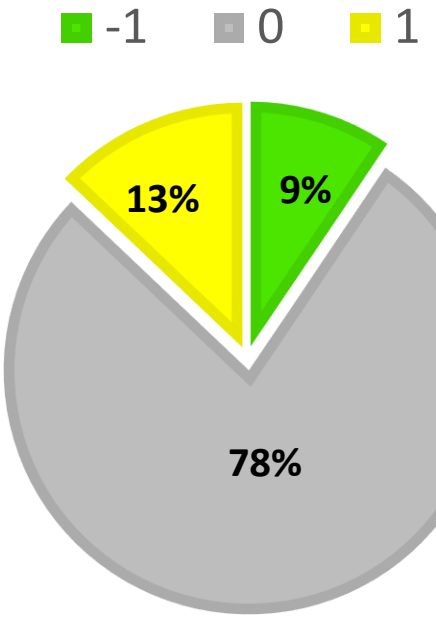


6. Comparative analysis of the used methods' results

6.2 Spatial Comparison

Comparative map of vulnerability to pollution between the DRASTIC method and the DRASTIV method

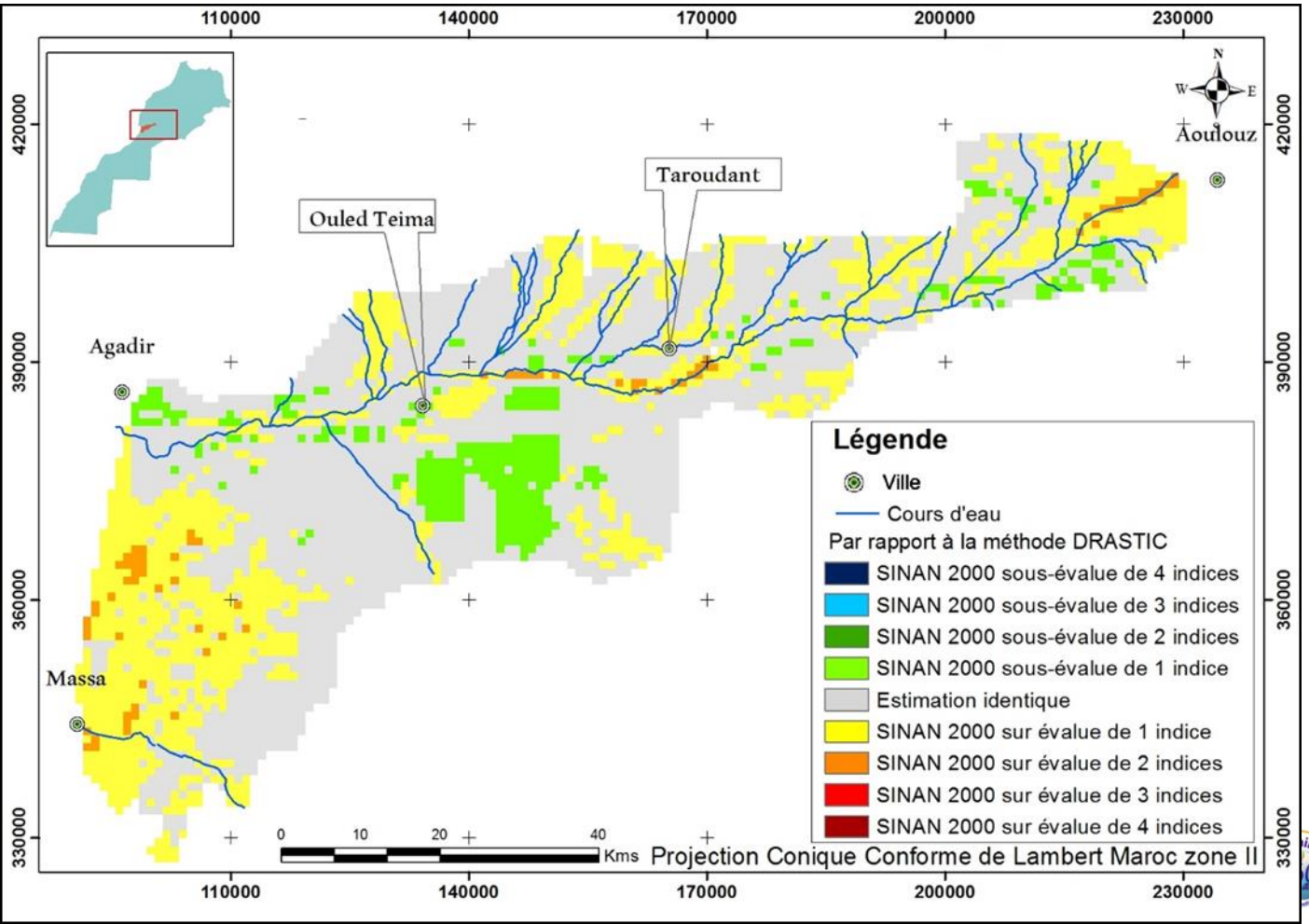


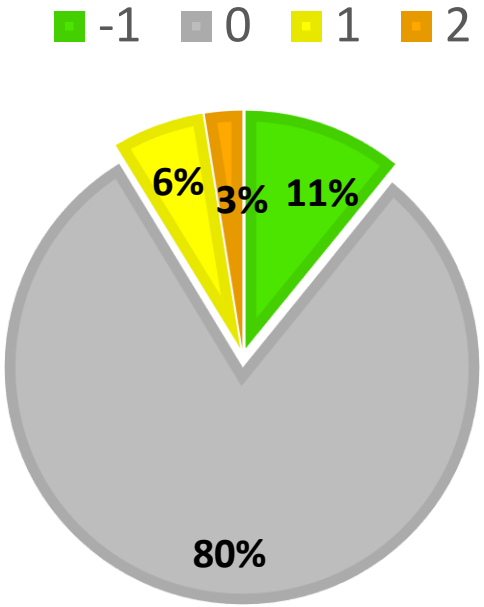


6. Comparative analysis of the used methods' results

6.2 Spatial Comparison

Comparative map of vulnerability to pollution between the DRASTIC method and the DRIST method (Sinan 2000)

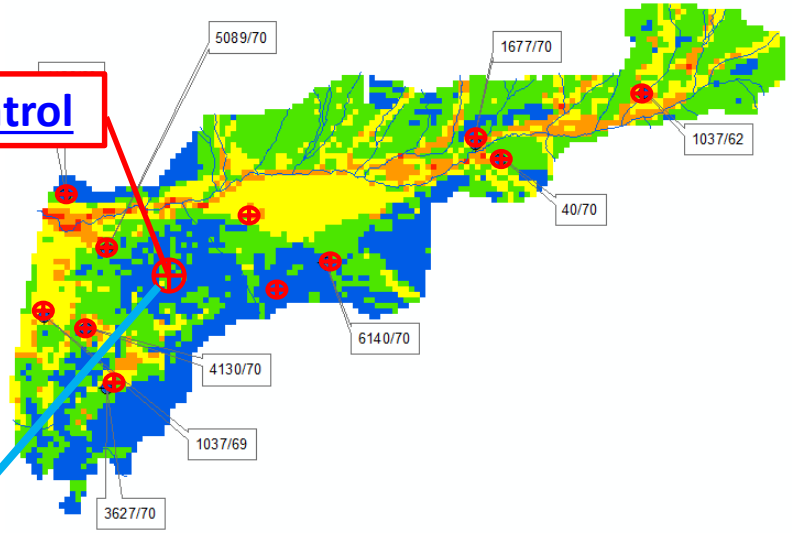




6. Comparative analysis of the used methods' results

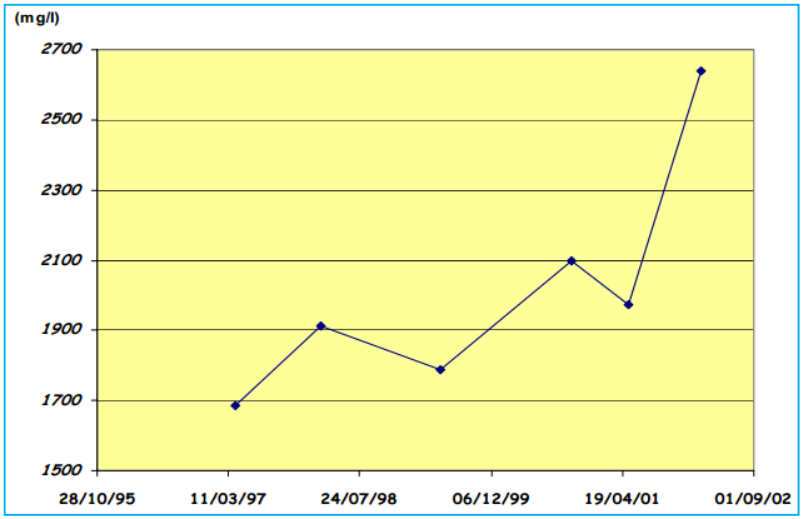
6.3 Test of validity by drilling Witness

Drilling control



Exemple :

Evolution of the dry residue in the Drilling



Evolution of :

- ✓Fecal coliforms;
- ✓Dry residue;
- ✓Nitrate content.

➔ **This quality of groundwater degrades in time**

Comparison with the results of six applied methods

6. Comparative analysis of the used methods' results

6.3 Test of validity by drilling Witness

Reference IRE	Coordinates X(m)	Coordinates Y(m)	Observation	Potentiel Source of pollution Nature	Potentiel Source of pollution Distance
3627/70	108250	349800	Equipped Wells intended to supply the Douar Tin Taled	Irrigated perimeter Industrial Unit	0 km 2.6 km
1677/70	174620	393920	Equipped drilling for the irrigation	Irrigated perimeter Dump Liquid Releases	0 km 0.77 km 0.78 km
1037/62	205000	403030	Equipped drilling for the irrigation	Périmètre irrigué Dump	0 km 4.8 km
1152/69	100600	384500	Equipped Wells intended to the watering of green spaces	Industrial zone Dump Quarrying	3,1 km 3,6 km 4 km
4130/70	104380	360500	Equipped drilling for the irrigation	Irrigated perimeter Dump	0 km 4.8 km
5089/70	108250	374830	Equipped Wells intended to supply the Kleaa	Dump Irrigated perimeter Industrial Unit	1.5 km 0.8 km 1.7 km
6140/70	147700	372400	Equipped Wells intended to supply the douar Nbikka	Irrigated perimeter	0,7 km
….	….	….	….	….	…

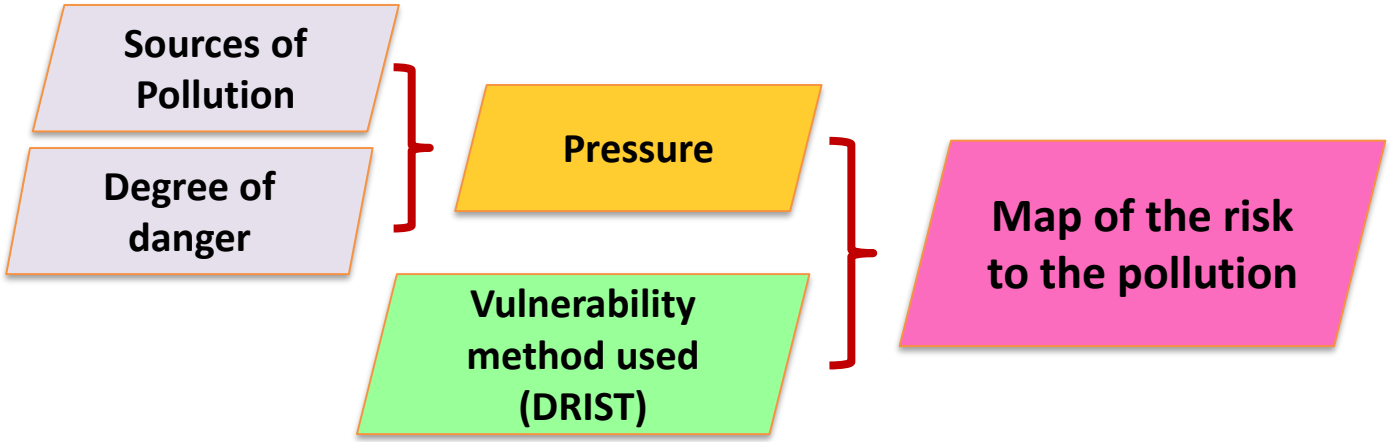
6. Comparative analysis of the used methods' results

6.3 Test of validity by drilling Witness

Drillings witnesses	Better characterization of the vulnerability to pollution by comparison to the evolution of groundwater quality in witness wells				
	DRASTIC	SINTACS	DRASTIV	SINAN 2000	Minnesota
3627/70	-	+	-	+	+
1677/70	-	-	+	+*	+
1037/62	-	-	+	+*	-
1037/69	+	-	+	-	+
4130/70	-	+	+	+	-
1152/69	-	+	-	+	+
40/70	-	-	+	+	-
6140/70	-	-	-	+*	-
5089/70	-	-	-	+*	-
Total	1/9	3/9	5/9	8/9	4/9
%	11%	33%	55%	89%	44%

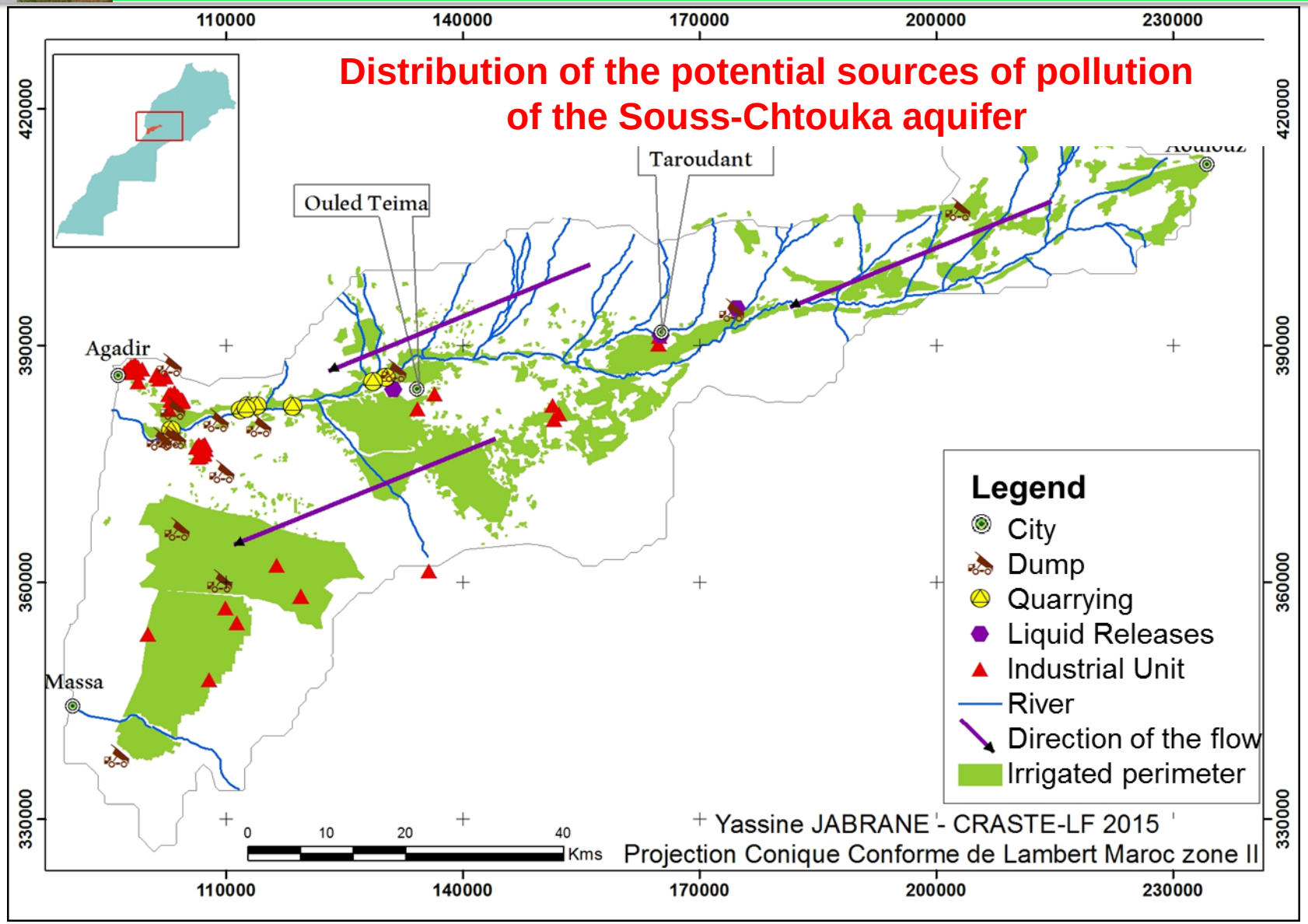
* : Sensitivity to pollution méthod (Sinan, 2000)

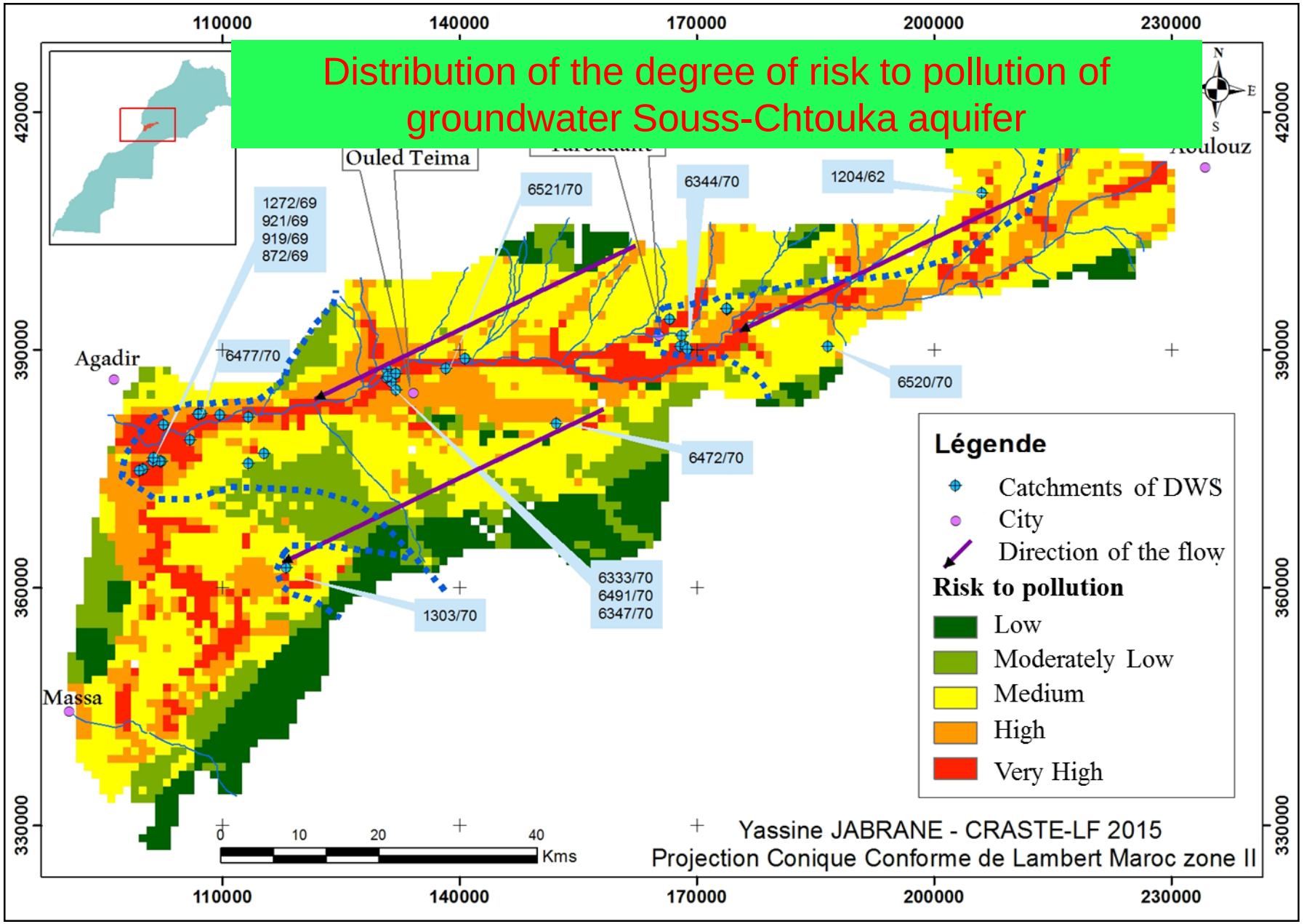
7. Mapping of the risk to pollution of Souss-Chtouka aquifer



Vulnerability to pollution	Degree of danger of pollution		
	Very low	**Medium**	**High**
Very low	Very low	Moderately Low	Medium
Low	Very low	Medium	Medium
Medium	Moderately Low	Medium	High
High	Moderately Low	High	**Very High**
Very High	Moderately Low	High	**Very High**

7. Mapping of the risk to pollution of the Souss-Chtouka aquifer





Conclusion

- ✓ The most representative method to characterize the vulnerability to pollution of Souss-Chtouka aquifer (porous environment) is the DRIST method (Sinan, 2000) ;
- ✓ The groundwater of Souss-Chtouka is a medium to high risk to the pollution ;
- ✓ Areas of high vulnerability and characterized as high risk to pollution are located primarily along the bed of the Souss River and in the coastal part of the Aquifer ;
- ✓ Most of the Catchments of DWS (drinking water supply) are located in an area of heigh to very heigh risk to pollution.

Recommandations

- ✓ Adopt the DRIST method (Sinan, 2000) to characterize the vulnerability to pollution of aquifers in porous medium;

- ✓ Delimitate and establish quickly the DWS catchments protection perimeters;

- ✓ Apply the principle of the polluter - payer of the new Water Act 36-16.

Thank you for your kind attention

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