Study Of Soils Salinity In Arid Area: Case Of Ouargla (Algeria)

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Abstract.
The objective of our work is to find the origin of salts on the soil surface, in order to limit the causes of agricultural soils salinization. The arid region of Ouargla lies on a groundwater table whose level is close to the soil surface (0- 1,5m). At this low depth, there can be a permanent movement of water from the groundwater to the soil surface. These can be very damaging when the groundwater has a high level of salinity.Waters subjected to strong evaporation tend to concentrate in salts and the soils to become salty. The results of our previous work have shown that the soil salinity is caused by the aridity of the area and the depth of the groundwater. The results of our current work show that the surface soil salts also depends on the salinity of groundwater.

Keywords: arid zone, degradation of agricultural soils, soil salinization, groundwater

INTRODUCTION

It is observed in palms and some regions a considerable degradation due to salt deposition. The latter is caused by the evaporation of the groundwater that has a high level of salinity to which is also very close to the soil surface and the highly mineralized water used for irrigation. These problems have been the subject of a good number of previous works (ENEGEO, 1990, Guendouz A et al, 1992, Nezli I, 2004), to explain the origin and the causes of this phenomenon. The aridity of the area helps to boost evaporation and increases the salt deposition in the root layer (El fergougui, 2012). The agricultural soils salinity growth have limited crop production and caused the sterilization of soils on several newly developed regions. The study of degradation is of great significance for the soil salinization mechanisms knowledge (Gouvea 1980, Gowing et al, 2006).
The objective is to study the role groundwater plays on the estimation of soil salinity.

USED MATERIALS

In order to determine the quantity of soluble salts in the soil in presence of a salty groundwater that is close to the soil surface of Ouargla's arid zone, observations have been made on the farm field of the University of Ouargla using 05 piezometers in the absence of irrigation (steady state).
The measurement campaign started from September 2011 to August 2012. The soil has a sandy texture. Fig1
In order to know the origin of the soil salinization and the water / soil relationship the National Water Resources Agency has installed piezometers to analyze the chemical composition of the groundwater during two sampling periods (February and June). Fig2.
The bowl of Ouargla is located in the south of Algeria, 790 km from the capital and on the wide basin of the M'ya river valley. It is at an average altitude of 137 m, its geographical coordinates according to the latitude is 31 ° 57 'North and the longitude is 5 ° 20' East.

METHODS

The depth of the groundwater is measured using an electrical probe type A.OTT 27-39.
The chemical analysis of the soil sample consists to determine the dry residue by filtration and drying at 110 ° C, it is based on the 1/5 method (Fig 3), (Fig 4), (Fig 5).
The soil sampling is effectuated over three depths (0-30cm), (30-60cm), (60-90cm), and over a radius of 1m at each piezometer. At the same time, the dry residue concentration of the groundwater is determined (Fig 6).

During the measurement campaign of the arid zone of Ouargla, annual rainfall was extremely low, insignificant even, their distribution being marked by an almost absolute drought from January until November with a maximum of 7mm in December, (NMO).
The ombrothermique diagram (Bagnoul. F et Gaussen. H, 1953), (Fig 7), shows that the drought period from 2010 to 2012 extends over the three years of observations. (Table 1)
This same phenomenon is observed in the years 2001, 2002, 2003, 2004. (Table 2)
During the measurement campaign the monthly average temperature varied between 7 °C and 40 ° C. The cold season lasted for five months from November to March, the monthly temperature varied between 7 ° C to 25 °C. In the warm period from April until October the monthly temperatures was between 25 °C and 40°C. The winds were generally low varying on average between 0.63 and 4.7 m / s.
The evaporation is very high; it varies between 100 mm and 200 mm in winter and reaches 600 mm in summer (El fergougui M, 2016). It varies greatly depending on the years, months and weeks.
Likewise, records in the period 1995-2000 (El fergougui M, 2003) showed an intense interannual evaporation of about 2199 mm / year. If we consider the year 2006, the rainiest year, with a total precipitation of 203 mm and a total of evapotranspiration of 3796 mm (El fergougui M, 2016). The Emberger aridity index applied by UNESCO (Cosandey C, 2000) for the Sahara (I) is:

$I = P/ETP.$ **(1)**

$I = 0.0534$

Ouargla is classified in a normal aridity zone.
P: annual precipitation in mm
ETP: annual evapotranspiration in mm
However, by calculating the aridity index (I) for the period 2000 to 2009.
$P = 57.94mm$: Average annual precipitation in mm
$ETP = 3367.48mm$: Average annual evapotranspiration.
We will obtain an index of aridity I = 0.017 which classifies the region of Ouargla in a zone with extreme aridity $I < 0.03$.

RESULTS AND DISCUSSIONS

Data from monthly measurements of dry residue deposition in the soil root layer (C_s), groundwater depth (h) and mineralization (C_n), shown in Tables 3 and 4 , allow to represent the distribution of point cloud between (C_s / C_n) according to (h) (depth of groundwater) Figure 8.
The connection between these three characteristics (Figure 9) is adjusted by a curve resulted from the measured data.
The physical model established is adjusted using an exponential function. The adjustment quality is calculated so that the adjustment precision can be evaluated. The maximum value of R^2 is 0.81 and the error is of 0.05. The function is expressed by the following equation:

$c_s = c_n e^{-0.67h}$ **(2)**

The difference between the measured values and the values determined by equation (2) are shown in Table 3. The adjustment curve shows that:
- Cs is equal to C_n when the groundwater is situated between 0 and 0.5 m; i.e., (C_s / C_n) → 1
- Cs varies between 80% and 50% compared to C_n when the groundwater is situated between 0.5 m and 1m.
-at a depth of 1.5 m, the ratio of (C_s / C_n) is less than 50%.
-Cs decreases to 10% compared to C_n when the groundwater is situated between 1.5m and 3m.
- Beyond 3 m, the ratio (C_s / C_n) becomes negligible.

The monthly deposits measurements analyses of the dry residue in the soil root layer (C_s) during the entire measurement campaign which was carried out in climates with high evaporation allowed us to show that the concentration of salt in the soil depends on the depth of the groundwater and its mineralization.
When the groundwater is near the soil surface (between 0 - 0.5m), the soils surface in contact with the aquifer have the salts concentration equal the aquifer mineralization.
-Over 1.5 m, salt deposits decrease considerably, according to Averianov S, 1978, Choumakov B, Beznina S, 1989, Pachkovski I 1988, Katz D, elfergougui 2016, this depth called critical depth, corresponds to the groundwater level for which evaporation provides a small deposit of soluble salts in the soil.
For the same groundwater depth, the dry residues concentration from the soil increases with the mineralization of the groundwater.
-In Piezometer 1 of the year 2012, where the groundwater depth was 1m and its mineralization was 15500mg/l, the dry residues concentration in the soil was 9060mg / l / month.
-On the other hand, for the same groundwater depth h = 1m in piezometer 76 for the year 2001 when the groundwater mineralization was 36000mg/l , the dry residues concentration of the soil root layer was 19428 m/l/month.
The results obtained in other previous studies achieved for high evaporation climates are as follows.
Barbiero L (1992) has shown, from the geochemical groundwater analysis results, that the chemical composition of the aquifer water becomes that of the soil solution, when the aquifer water comes into contact with soils.

Borovski, V.M (1982) established a direct relationship between mineralization and the groundwater minimum depth, it must be maintained in order to avoid a huge deposit of soluble salt in the root layer.
According to Ben Hassine H (2005), the critical depths for sandy soils vary between 1.3 and 1.5m.
The monthly deposits measurements analyses of the dry residue in the soil root layer (C_s), during the entire measurement campaign which was carried out in climates with high evaporation, allowed us to show that the concentration of salt in the soil depends on the depth of the groundwater and its mineralization.
It should be noted that our previous experimental work result effectuated to determining the inflow of the groundwater depth on its evaporation [El fergougui 2016] converge towards the same following conclusions fig 10.
1 - The evaporation of the groundwater (E_n) is maximum when the piezometric level is close to the ground (between 0 and 0.5m). The Evaporation of the groundwater in this case is equal to the evapotranspiration (E_o).
2- The Evaporation (E_n) becomes less sensitive as the level of the groundwater is distant from the surface of the ground and is zero at a certain depth called "critical depth.

CONCLUSION

The improvement and stabilization of crop yields in arid and semi-arid regions can only occur if the mineralized groundwater is maintained (drained) in a depth of 1.5m. this depth corresponds to the groundwater level for which the latter provides a low deposit of soluble salts in the soil.
As presented, a noticeable accumulation of soluble salts will occur in the soil root slice from 0 to 1m when the depth of the mineralized aquifer is at a depth of less than 0.5 m.
The established function can be used to estimate the monthly amount of soluble salts deposited in the soil root layers according to the groundwater mineralization and its depth in arid sandy-textured regions in preliminary studies.

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Table 1. Climate data of Ouargla (2010, 2011, 2012) National Meteorological Office of Ouargla (NMO)

	Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	Average temperature (°C)	17.8	20.3	24.7	27.5	34.4	40,9	44.6	43.0	42	35	28	22.9
	Precipitation (mm)	3.2	0	0	0	0	0	0	0	0	0	0	4.1
	Average wind speed (m/s)	4.1	3.0	36	2.7	4	3.8	2.2	1.6	3.7	2.4	2.1	1.4
2011	Average temperature (°C)	18,5	20.9	25.5	30	34.8	41	43.7	44	43	32	24	20
	Precipitation (mm)	1,4	0	0	0	0	0	0	0	0	0	0	7
	Average wind speed (m/s)	2,8	2.8	3.8	4.4	4.8	4.6	4.2	4.0	3.8	3.5	2.8	2.7
2012	Average temperature (°C)	23	22	2	30.4	36	45	44.8	46	44	39	26.3	19.9
	Precipitations (mm)	1,4	0	0	0	0	0	0	0	0	0	0	1.1
	Average wind speed (m/s)	2	2	1.3	2	2	1.3	3.5	1.5	1.5	1.2	1.4	1.2

Table 2. Climate data of Ouargla (2001, 2002, 2003,2004) National Meteorological Office of Ouargla

Year	Parameters	Jan	Feb	Mar	Api	May	June	July	Aug	Sep	Oct.	Nov.	Déc.
2001	**Maximum temperature (°C)**	19.7	21.1	30.4	29.0	34.9	40.9	46.2	42.6	41	35.3	24.3	18.1
	Minimum temperature (°C)	8	8	13.3	14.5	20.0	25.3	28.2	28.0	25.1	20.7	10.5	5.3
	Relative humidity %)	54	53	39	35	33	25	24	28	41	42	58	65
	wind speed (m/s)	2.5	2.3	3.4	3.9	5.1	4.0	4.2	3.4	4.2	2.8	2.8	3.0
	Evaporation (mm)	146	149	254	296	381	492	540	484	379	298	154	105
	Precipitation (mm)	0	0	0	00.4	0	0	0	0	01.0	00.6	00.3	03.6
2002	**Maximum temperature (°C)**	17.4	22.5	26.9	29.4	34.8	31.9	44.0	42.4	42	31.0	24.6	21.0
	Minimum temperature (°C)	8.6	9	13	15.4	20.8	24.9	29.0	28.3	23.6	16.2	11.1	06.7
	Relative humidity(%)	50	55	37	32	29	23	26	29	37	47	56	60
	wind speed (m/s)	2.4	1.6	3.2	4.4	4.7	3.6	4.8	4.0	1.6	3.0	2.9	1.9
	Evaporation (mm)	101	157	246	299	374	435	426	473	337	235	176	119
	Precipitation (mm)	0	0	0	0	05.0	0	0	02.4	01.5	02.6	02.4	0

2003	**Maximum temperature (°C)**	23.3	18.9	18.6	30.2	35.4	33.7	44.6	41.4	44	35.8	24.1	18.5
	Minimum temperature (°C)	10.0	10.5	06.4	15.5	20.9	25.0	29.4	26.5	23.3	20.5	10.7	05.8
	Relative humidity(%)	48	55	58	35	32	28	29	26	36	42	53	56
	wind speed (m/s)	4.0	4.0	3.3	4.6	4.7	3.9	5.5	4.0	3.5	3.4	2.5	3.6
	Evaporation (mm)	196	138	122	309	404	439	538	468	329	268	141	116
	Precipitation (mm)	06.1	06.4	15.5	0	0	0	0	0	0	03.9	00.2	00.2
2004	**Maximum temperature (°C)**	19.0	22.3	26.2	28.5	31.7	39.3	41.6	46.8	35.4	33.0	20.1	18.5
	minimum temperature (°C)	11	08.6	12.4	15.6	17.7	24.4	26.9	28.9	22.4	18.6	10.6	08.2
	Relative humidity %)	56	47	43	39	37	30	26	27	37	37	73	66
	wind speed (m/s)	2.7	3.6	4.3	3.8	5.5	4.5	3.8	3.5	3.7	3.6	2.6	2.9
	Evaporation (mm)	100	161	249	283	371	480	512	513	367	310	082	09.8
	Precipitation (mm)	06.5	0	21.7	05.4	0	00.2	0	13.1	0	19.6	43.3	08.0

Table 3. Comparison between the measured and determined equation of the soil monthly average dry residue. Period from 2011 to 2012

Nº piezo-meter	Period	Number of days	Depth of Grounwater M	Monthly Average dry residue of the soil (Root layer) measured C_S	Dry residue of the groundwater C_N	C_S/C_N Determined by measurement	C_S/C_N Determined by equation	Error
	Year 2011	days	M	**mg/l/month**	**mg/l**	%	%	
	sept 9 th to nov	60	1.36	5940	12320	43	41	0.05
	12th	21	1.36	5600	12090	46%	41	0.12
P1	nov12th to dec 2th							
	Year 2012							
	dec 2nd tojan 21th	52	1.49	2917	6785	41%	37	0,09
	jan 21th to	35	1.35	3878	8813	44%	41	0.24
	feb25th	22	1.36	4570	9695	47%	41	0.07
	feb 25th to	22	1	9060	15500	58%	52	0.12
	mar19th							
	mar 19th to							
	jun10th							
	Year 2011							
	sept 9th to nov	60	0.9	7850	13000	60	55	0,08
	12th	21	0.68	7200	12000	60	64	0.06
P2	nov 12th to dec							
	02nd							
	Year 2012							
	dec 02nd to jan	52	0.67	7	10914	67	64	0.07
	21th	35	0,66	5975	9519	63	65	-0.03
	jan 21th to feb	22	0.58	8055	11000	73	68	0.07
	25th	22	0.58	11000	15500	71	68	0.04
	feb 25th to							
	mar19th							
	mar 19th to							
	jun10th							
	Year 2011			5116		62	57	0,07
	sept 9 to nov	60	0.84	6070	8287	63%	54	0.15
	12th	21	0.94		9625			
P3	nov 12th							
	todec02nd							
	Year2012							
	dec 02nd tojan	52	0.83	5140	8453	61	58	0.05
	21th	35	0.71	5866	8807	67	63	0.07
	jan 21th to feb	22	0.68	7819	12611	62	64	0.03
	25th	22	0.72	6930	10000	69	62	0.1
	feb 25th to mar	51	0.82	5436	8986	60	58	0.03
	19t							
	hmar 19th							
	tojun10th							
	jun 10th to							
	augt31st							
	Year1011							
	sept 9 to nov	60	1.45	5660	9664	35	38	-0.1
P4	12th							
	Year2012							
	dec 02nd tojan	52	1.14	5060	9908	51	47	
	21th	35	1.0	6850	11056	52	50	0.08
	jan 21th to	22	0.7	5760	9471	61%	63	0,04
	feb25th	22	0.7	5750	9449	61%	63	-0,04
	feb 25th to							-0.04
	mar19th							
	mar 19th to							
	jun10th							

	Year2011			2770			27	0.17
	sept 9 to nov	60	2	3280	8604	32	28	0.22
P5	12th	21	1.95		9306	35		
	nov			3205			28	0.20
	12thtodec02nd	52	1.92	4530	10341	31	28	-0.13
	Year2012	32	1.91		18083	25		
	dec 02nd							
	tojan21th							
	jan 21th to							
	feb25th							

Table 4. Dry residue of the soil and dry residue of the groundwater. National resources water agency period 2001-2002-2003-2004 (ANRH) from May 15h to February 25th and February 25th to May 25th during two successive seasons 99 days each

Nº piezometer and period	**Depth Ground water**	**Dry residue of the ground water**	**average dry residue of the soil (root layer) measured C_S**	**Depth of Ground water**	**Dry residue of the groundwater CN**	**monthly average dry residue of the soil (root layer) measured C_S**	**Depth Ground water**	**Dry residue of the ground water CN**	**monthly Average dry residue of the soil (root layer) measured C_S**	**Depth of Ground water**	**Dry residue of the groundwater CN**	**monthly average dry residue of the soil (root layer) measured C_S**
	m	mg/l	mg/l/month	m	mg/l	mg/l/month	m	mg/l	mg/l/month	m	mg/l	mg/l/month
P 113	year 2001	year 2001	Y year 2001	Y year 2002	Y year 2002	year 2002	year 2003	year 2003	year 2003	year 2004	year 2004	year 2004
may15h to feb25th	3.7	88300	2580	3.85	90000	2700	3.62	30000	888	3.76	83200	2478
feb25th to may25	4.9	105000	3060	4.72	114000	3450	4.05	9000	1176	4	98000	2943
P 121	6.7	2900	90	6.85	31600	960	6.3	3500	120	7.81	3 100	84
	7	105000	3090	4.72	114000	3420	4.05	39000	1155	4	98000	2907
P 178	6.4	22600	690	6.5	3600	120	6,46	22000	639	6.62	21400	660
	1.9	4500	1350	7.6	3600	102	8	29000	843	7	25000	708
P 76	0.4	25810	21990	0.62	15500	12528	0.39	37000	27600	0.82	56600	45900
	1	36000	19428	1.1	21000	11316	1.2	4500	24300	1.1	65000	35040
P 99	1	19200	12540	1.09	26000	14070	1	17600	9516	0.94	16400	8850
	1.9	3300	960	5	39000	1194	5	25000	717	4	22000	696
P 67	1.1	96600	52170	1.23	89000	48150	1.14	64200	34740	1.02	36000	19449
	2.3	1100	330	3	90000	2760	1.55	74000	14550	5	45000	1314
P 168	4.6	15800	468	5	30000	879	4.63	26800	774	4.52	24800	693
	4.9	21000	630	4,3	39000	1140	5	39000	1134	5.1	32000	954
P 59	11	2500	81	11	5200	126	6	2370	60	5	2 300	60
	5	3000	90	11	6300	180	5	2900	93	6	3 200	90
P4	1.4	38400	17763	4	4500	150	1.37	362600	141000	5	79200	2349
	2	55000	13500	2.01	69000	2049	2	402000	48000	3	86000	2550
P 23	1.3	160000	86460	1.4	135000	72990	1.8	109320	18000	1.28	110800	59790
	1.9	17500	6660	1.99	121000	5988	2.1	18500	5310	5	13300	369
P33	3.9	10000	336	4.25	85000	240	3.87	7840	228	3.12	8 800	270
	4	11000	330	4.9	9000	243	3.99	9100	258	2.5	9 000	246

©Google map, 2012

Figure1. Experimental site

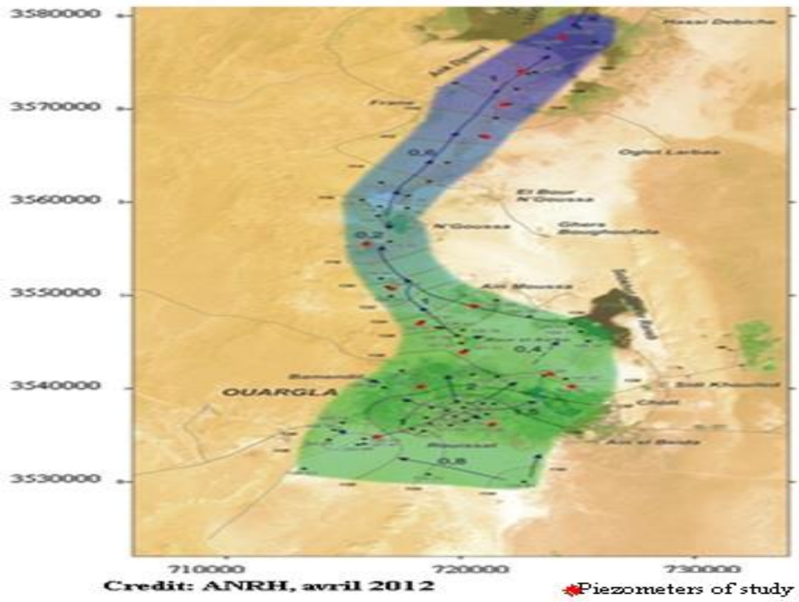

Figure2. Implantation of piezometers

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Figure 3. stove

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Figure 4. Electric stirrer

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Figure 5. Electric balance of 10^{-4} readability

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Figure6. Soil samples of 3layers (0-30cm), (30-60cm), (60-90cm) and groundwater

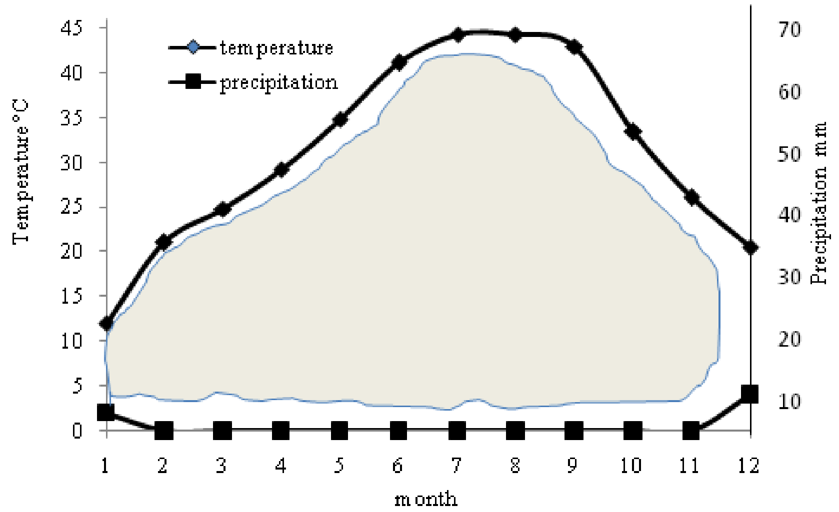

Figure7. Ombrothermique diagram in Ouargla for three years (from 2010 to 2012)

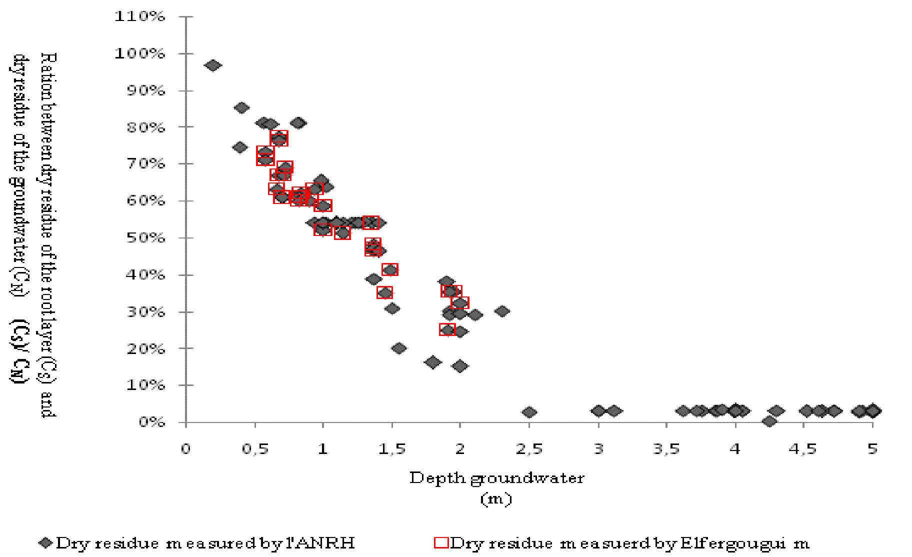

Figure 8: Point cloud of the dry residue measured during the 2011-2012 campaign and the ANRH's campaign

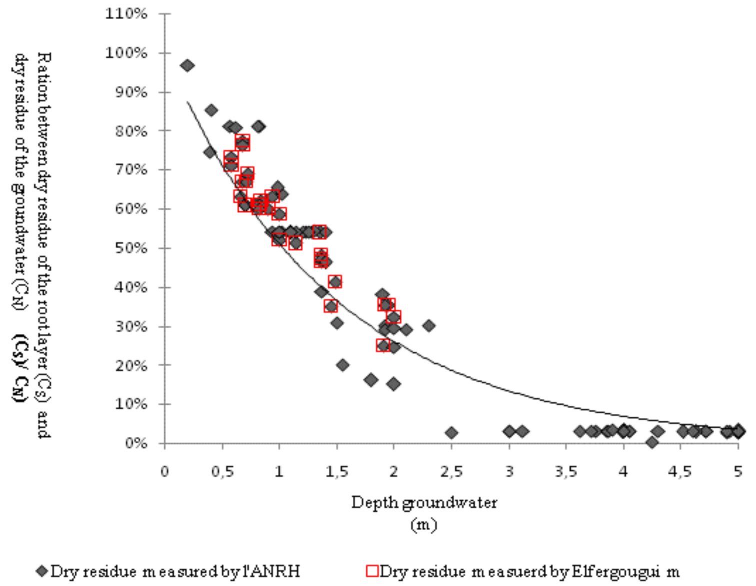

Figure 9: Curve adjusted to the dry residue measured during the 2011-2012 campaign and the ANRH's campaign

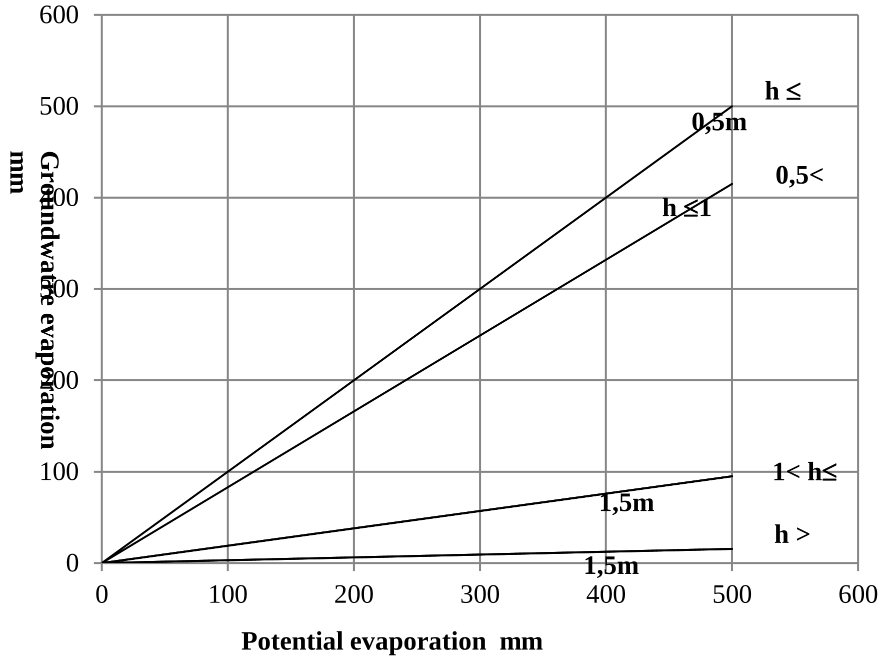

Figure 10. Abacus to determinate the evaporation of the groundwater according to its depth (h)

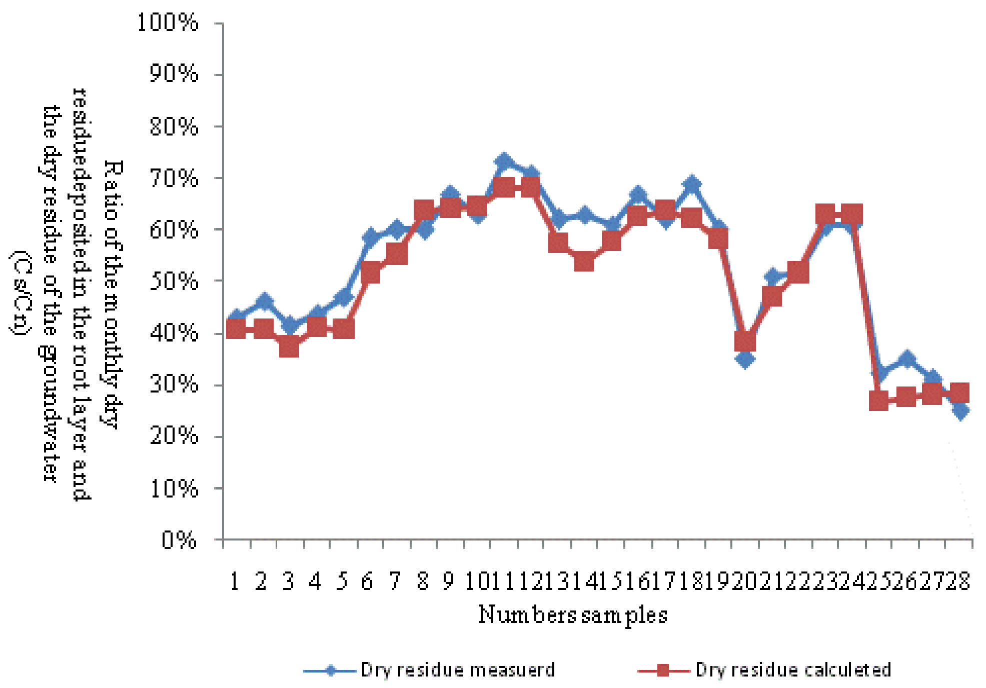

Figure11. Comparison of the measured and calculated dry residue of soil of 1m depth