SSRG International Journal of Geo-informatics and Geological Science Volume 8 Issue 2, 106-115, May-Aug, 2021
ISSN: 2393 – 9206 /doi:10.14445/23939206/IJGGS-V8I2P109

Analysis of The Spatio-Temporal Variability of Water Storage In A Rural Landscape And Integration Into GIS. Case of Kamech Catchment

Faiza Khebour Allouche[1&2], Insaf Mekki[3], Arwa Hamaideh[4], Anas Khasawneh[5], and Meriem Fgaeir[1]

[1] *High Institute of Agronomic Sciences-Chott Meriem, University of Sousse, Tunisia*
[2] *GREEN TEAM Laboratory, University of Carthage, Tunisia*
[3] *National ResearchInstitute of Rural Engineering, Water and Forests (REF), Tunis, Tunisia*
[4] *Water, Environment, Center Energy research. University of Jordan*
[5] *Jordan Association for Building Environment and Sustainable Development, Jordan*

Received Date: 12 July 2021
Revised Date: 16 August 2021
Accepted Date: 27 August 2021

Abstract - *Quantifying the Spatio-temporal variability of available water storage is very important for assessing agricultural production and flood genesis. The main purpose of this paper is to study these Spatio-temporal variations of groundwater. The Lamech watershed (263 ha), located in Cap Bon of Tunisia, was chosen as a study site. It is mainly characterized by soils of a vertic nature and slopes varying from 0 % to over 30 %. Six sites were selected to perform weekly measurements of soil moisture contents during the period, which ran from 19 February until 7 May 2014. The essential criteria which led to the choice of these sites are the diversification of topographical and soil factors and their proximity to the experimental stations. The gravimetric and neutron methods were used to measure soil moisture profiles from the surface to a depth of 1 m at 0.1 m depth increments. The results showed that the Spatio-temporal distribution of surface soil moisture of the studied sites is governed by several factors (rainfall, topography, etc...). The results of statistical analyzes also proved a correlation of available water storage with the land use, previous crop, and slope. This spatial distribution of soil water content over the study area has been integrated into a GIS, thereby constituting a means of spatialization of available water storage across the entire watershed. The resulting map of the spatial distribution of available water storage was prepared in ArcGIS software considering data on soil type and slope. This allowed us to assess the amount of available water for plants that can be stored in the watershed. This value is of the order of 988,893 m^3, or approximately 7 times the storage capacity of the lake hill reservoir (142 000 m^3).*

Keywords - *Soil moisture, available water, Spatio-temporal variability, cultivated watershed, GIS.*

I. INTRODUCTION

In Tunisia, the overall mobilization of water resources and their optimal allocation has always been sought. The investments allocated to the mobilization and storage of surface water and exploitation of groundwater have led to a remarkable development of agricultural water. In this context, soil moisture is defined as evaporable water contained in the floor portion is located above the water table. It is the major source of water from the land surface in the maintenance of life on Earth. A precise knowledge of soil moisture and its spatiotemporal evolution is key to monitoring the growth of vegetation, predicting agricultural production, improving water resources management as well as weather forecasts, and including a better understanding of the processes of water transfer in the soil. Indeed, soil moisture is a key parameter in the energy exchanges in the surface-atmosphere interface. Evaporation, infiltration, surface runoff, and the amount of water absorbed by vegetation are highly dependent on soil moisture. It is, therefore, a key parameter of the hydrological cycle.

The regions with the semiarid Mediterranean catchments provide an important way for agriculture include for this purpose the Cap Bon region, located northeast of Tunisia, which is marked by the presence of a large number of the watershed hill, which was built to mobilize water resources for agricultural production. The choice of the study site fell on the watershed Kamech located on the end of the Tunisian dorsal (Cap Bon, northeast of Tunisia). Since 1994, this watershed has belonged to a network of thirty experimental watersheds, including small lakes on the Tunisian dorsal. This network is part of a research agreement between the Department of Water and Soil Conservation of the Ministry of Tunisian agriculture (Conservation of Water and Soil, Tunisia) and the Institute of Research for Development (IRD, France). Since 2002, the watershed Kamech became an experimental site ORE MORE. The study of water storage in the soil of the

Kamech watershed requires the implementation of different methods of analysis and observation. They must be used to characterize the water stock in soil and to identify factors of variation of this stock. These methods are, on the one hand, quantitative and the other qualitative, whose objectives are: i) Analysis of the spatial and temporal variations in the water stock in the six study sites; ii) The identification of the main factors of variation in water stock; iii) The creation and management of a GIS-Stock water database and iv) The application of a spatial test the water stock across the watershed.

II. MATERIALS AND METHODS

A. Study site

The study area is the watershed Kamech, which is one of the main watersheds in the Cap Bon region that has been monitoring the water balance and erosion since 1994. Then, in 2002, it was part of an Environmental Research Observatory benefiting human, material, and financial resources. Its experimental device comprises a water level automatic station and a small dam used as a sediment trap. Watershed "Kamech" is located on the northwest mountains of the Cap Bon peninsula, east of Tunisia Nabeul Governorate. It is located on the edge of bioclimatic sub-humid and semi-arid Mediterranean floors and occupies an area of 263 ha (Figure 1). This watershed is drained by the Oued El GAMH, a small tributary of the wadi Zéroga which empties itself in the Oued El Ouidiane, one of the two main branches of the Oued Lebna. It flows into a large dam (24.7 million m^3) before emptying into the Mediterranean Sea Menzel Horr. Watershed "Kamech" extends between the geographical coordinates: 10 ° 52'-10 ° 53'E and 36 ° 52'-36 ° 53'N. It is the mountain range of Jebel Abderrahmane, which rises to 637 m and is the last foothills north of the Tunisian Dorsal [1]. The Lamech watershed is characterized by spoke asymmetry of the landscape: the right bank has a relatively dense river network explained by the existence of a gully erosion developed enough to generate a morphology "badlands". At the same time, the left bank has a less dense river network with generally longitudinal section bearings. Each level corresponds to the existence of a thick sandstone bar [2].

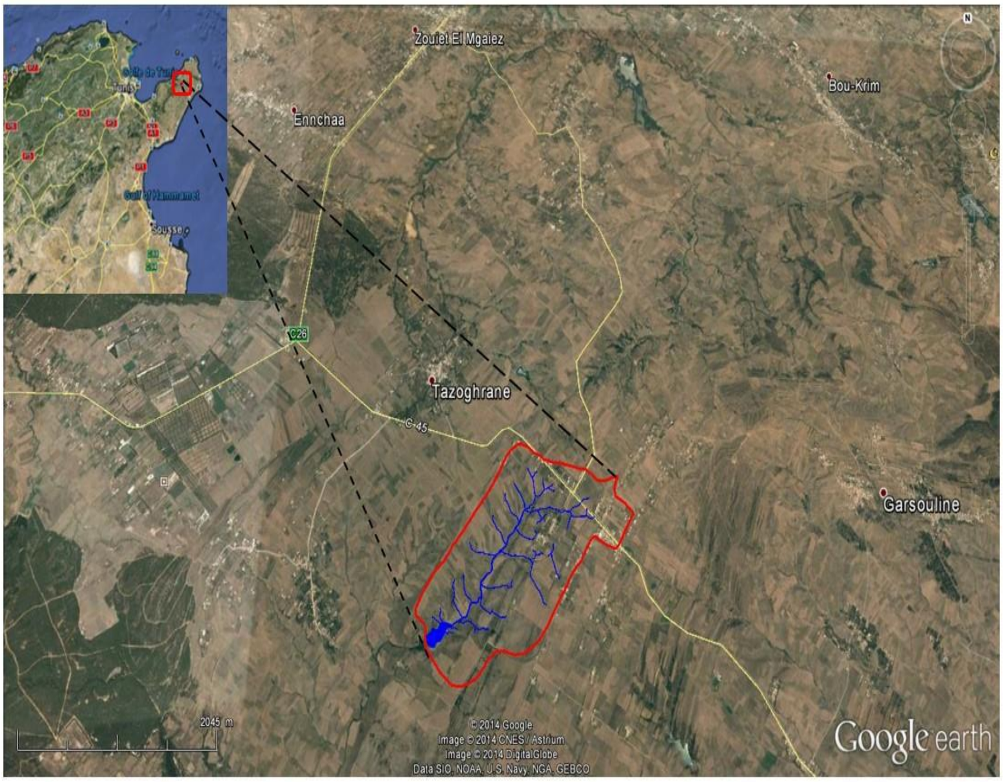


Figure 1. Study area location

B. Measurements and data collection

Six sites were chosen for measurements (Figure 2). The spatial distribution is as follows: five sites on the right bank of the watershed and 1 profile next to the wadi. The first measurement sequence (High Versant1, High Versant2 and High Versant 3) covers the experimental agronomic plot, the choice of which was based on the existence of various usable data in the interpretation of the results and important for understanding the variability of the stock water in the soil (pedological, topographical and climatic data). The second measurement sequence (Mid-Versant1, Mid Versant2, and shallows) was selected to explore the topographic effect. According to a survey conducted in the study area, the previous year's crop precedence for sites HV1, HV2, HV3, MV1, MV2, and BF are respectively: oats (for the first three sites), oats, and barley (the next two sites) and barley mixed with clover. The soil type, taken from the soil map of [3], varies even for two sites that are close; we find a truncated or eroded podsolic soil (HV1), called magnetic soils, carbonate, limestone, on marl and hydraumorphic (HV2, HV3, and MV1), a little soil evolves, erosion, regozolic, on marl and Vertisols, with external drainage reduced, vertically, on marl for the site of the left bank of the catchment. The following table summarizes the different characteristics of each site.

The spatiotemporal variation of soil moisture content was measured at the Kamech catchment scale using a neutron probe, gravimetric measurements near the location of the probe access tubes were also carried out along a meter deep. The monitoring started from 19 February 2014 until 7 May 2014 for different soil moisture conditions. Carried out for almost 3 months: from February 19th to May 7th, 2014, and gravimetric and neutronic measurements have been taken, and all information collected has been stoked in the GIS database.

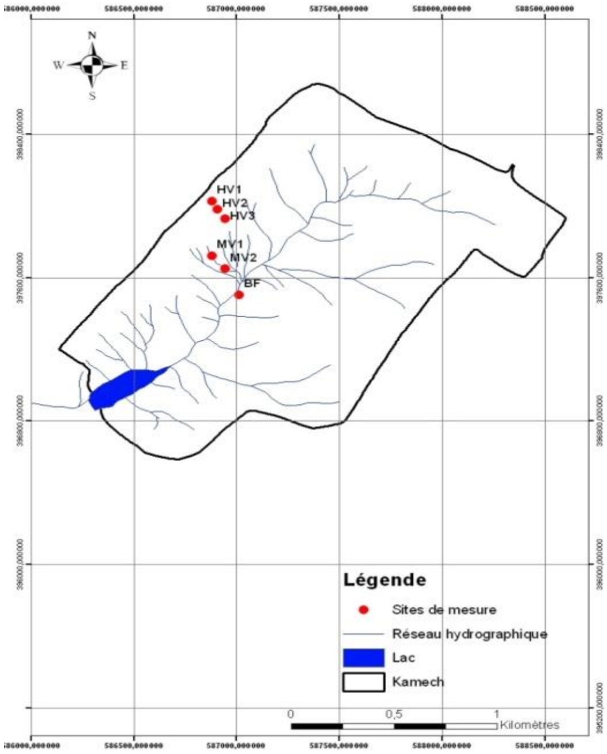


Figure 2. Location of soil moisture measurement points

III. RESULTS AND DISCUSSION

A. Analysis of the main factors of variation of water storage in the soil

The most important factors controlling the spatial variability of the water content of the soil are the climate (rainfall, ETo), soil, topography (slope and orientation), and some cultural techniques (land, labor, and previous crop soil).

a) Relief

The altitude of the sites varies from 90m to 190m. The highest point is located in the site HV1 with 152.64 m. The lowest point is localized in the BF site for altitude 110 m. The DTM two derived maps were developed, namely the slope map and the directions. Figure 3 shows that the entire watershed contains 5 slope classes, and the geolocation sites on this map show that MV2 has the highest percentage (16.26%). The HV1 sites and MV1 exhibit almost similar slopes variations that deviate from 11 to 12%. The sites and HV2 HV3 have the lowest values, with almost 9.5%. BF site located in lowland has a near-zero slope. Figure 4, with its 10 intervals, indicates that the studied sites have different orientations. Southeast succeed HV3, HV2 HV1, and then the rest of the sites have the same north-west orientation.

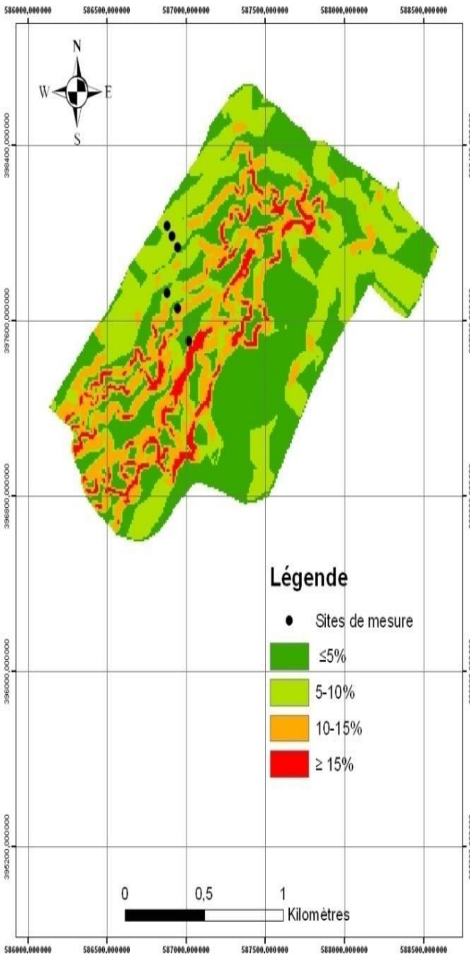


Figure 3 : Slope map

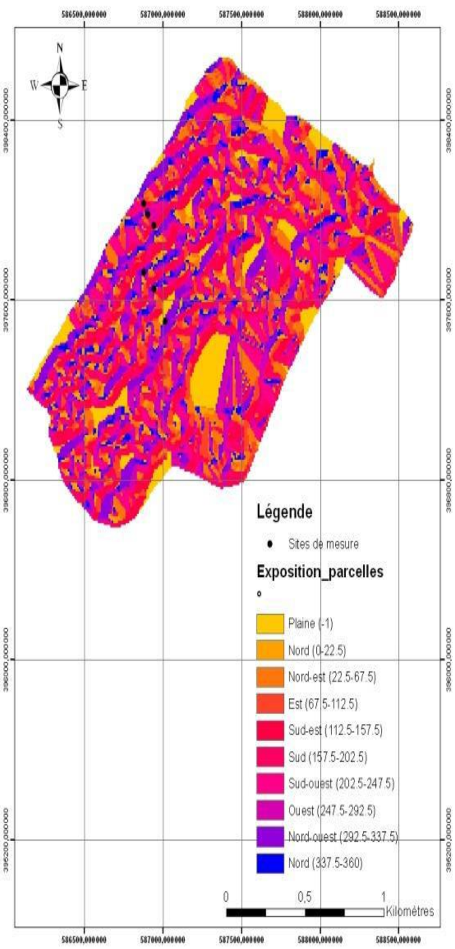


Figure 4: Map directions

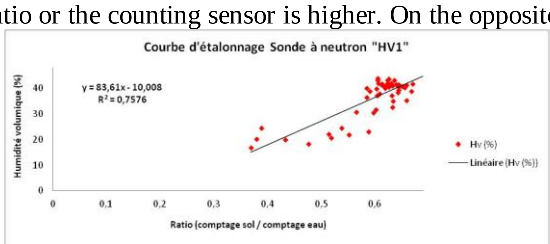
B. Analysis of soil moisture profiles

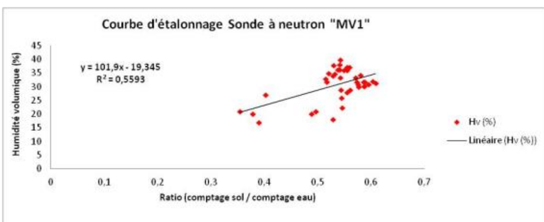
The gravimetric method allows control of the spatial variability of soil moisture since it is impossible to keep the same sampling point for each measurement, while the neutron method controls the spatial and temporal variability in one place. In this respect, the gravimetric method was used for the calibration of the neutron probe.

a) Calibration of neutron probe

Figure 5 shows a linear regression between the obtained count ratio relative humidity and volume (Hv) as measured by the gravimetric method. The experimental calibration equations characteristics for each sampling site are shown in the graphs. Each equation shows the correlation between the direct measurement (gravimetric measurement) and indirect (neutron measurement) of soil water content. It shows the concentration of the points related to the values of the volumetric water side of the highest values of the ratio or the counting sensor is higher. On the opposite side, the points are more dispersed and lower in proportion. This distribution is explained by the fact that the majority of measurements were carried out in the wet season.

This experiment shows that coefficient b varied from one site to another after extrapolation outside the measurement area. Furthermore, the values of R^2 are high (between 0. 65 and 0.85), so the measures are well correlated. Therefore, the R^2 correlation coefficient is close to 1 over the variances of a and b, contributing to the calibration error being minimized [4]. Obtaining the calibration curves for each site allows to stop using the gravimetric method, simply perform the measurements of water content with neutron probe, calculate the ratio counting, and project the value on the curve calibration for volumetric moisture percentage, for this it is necessary to increase the number of measurement points and expand the range of water content values from different soil moisture conditions (close to saturation and dry).





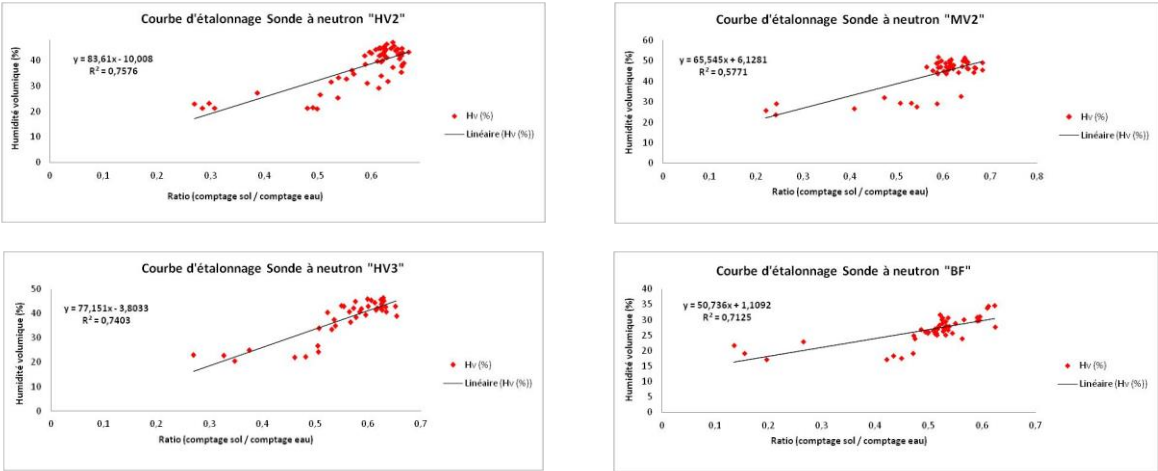


Figure 5. Site-specific calibration between neutron probe counts and total soil water content

C. Spatial variability of water storage in the soil

Figure 6 shows the evolution of water profiles in the six sites measured along a meter deep at the scale of the watershed on different dates of measurement. The general appearance of the variation of volumetric water for all sites is almost the same. However, a widespread net difference for each is to the levels of two layers of surface soil and average depth intervals: [0 -20] and [20-30]. The deepest layer [30-100] shows smaller fluctuations. For each site, the general appearance of the evolution of the volume humidity is generally toward increasing depth and then remains relatively constant to the deep layer with a slight decrease in the last few inches deep.

- For the first twenty centimeters deep [0-20] cm, volumetric moisture focuses between 16.85% (May 7) and 37.68% (March 12) for all sites (the range of 20.83% variation is small only).

The moisture profile of the BF Site (green curve) is extrapolated to the left of the figure, while the moisture profile of the site MV2 (red curve) is the right boundary. So it contains maximum moisture compared to the BF site that presents the lowest humidity. But this order is different for two measurement dates (12 and 27 March), where HV3 is the site that became the wettest. Generally, moisture curves are quite tight, and the average interval of variation is of the order of 20.83%. For example, this interval is 6, 81% on April 23 and 14.49 % on April 12. During these dates, volumetric moisture at different sites is near. The curves HV1, HV2, and HV3 present the closest profiles, so they contain similar water supplies. However, the fluctuation of the BF site profile taken on March 27 was mainly due to a measurement error.

- On the way to the depth [20-30], the percentage of volumetric moisture ranges from 18.39% (May 7) to 49.29% (April 17) for all sites. With a 30.9% variation interval.

A similar order of location of the moisture profile than the layer above was noted, and a slight spacing of more of them: that is to say, a range of variation of the water content of the soil large (reaching 30.9%). A very significant increase in soil volumetric moisture settles. The site MV2 (red curve) keeps volumetric moisture pronounced compared to other sampling sites. The moisture profile of the site MV1 (purple curve) is situated next to the BF profile, so this site is dry enough relative to the site HV3 (orange curve) that stores a relatively high water content. Profiles HV1 HV2 sites (dark and light blue curves, respectively) are at the other intermediate moisture profiles with sharp fluctuations along with the depth as well as along the measurement period. The humidity profiles remain tight for dates 17 and April 23, which results in small change in humidity. It is more important for other moisture measurement dates.

- On the way to the depth [30-100], volumetric moisture ranges from 25.18% (May 7) to 55.86% (March 12) for all sites (30.68% difference of HV). Soil moisture curves keep some consistency along with this layer of soil and a related site for all sites. The moisture profile of the BF site is extrapolated to the left of the figure, while the moisture profile of the site MV2 is the right boundary. So it contains maximum moisture compared to the BF site that presents the lowest humidity. In the MV2, March 12 registers a maximum humidity is about 60% below the ground in the last two feet of the importance of water stock in this resort during the measurement period. Generally, the MV1 site occupies a water content slightly higher than that of BF, HV1 and HV2 are succeeded (near water content), HV1, HV3 MV1 and in order of increasing water content. This order shows a reversal for any measurement date at the HV1, HV2 sites that are very close in terms of volumetric moisture.

There is a reversal of the order of water content for HV2 sites and MV2 who maintain a high water content compared to other study sites and slight moisture inversion for MV1 and HV2 sites. Deeper, each site keeps almost the same volume with the same moisture humidity difference order in the different sites.

MV1 generally differentiates approximately 20% moisture, only more compared to that of the BF site.

- The analysis of moisture profiles at the surface soil [0-20] for each site and a site to another emerges the following interpretations: the low levels of soil water compared to deep reflects flows between the atmosphere and soil evapotranspiration phenomenon at the level of the topsoil. The small change in volumetric moisture between HV1 sites HV2 and HV3 is explained by the plow their ground. The slight fluctuation from one site to another at this layer is on a reworking of clay soils by the development of vegetation and shrinkage cracks. The exposure of the plot of the site MV2, which is northwest, greatly influences the distribution of water in the surface layers of the soil. In fact, the interception of solar radiation by the ground depends on the sun's position, which itself increases the evaporation of water.

The analysis of moisture profiles at the moderately deep soil layer [20-30] for each site and a site to another may explain the sharp increase of the volumetric moisture by the fine texture of this layer and the low bulk density of the latter were large water retention.

- The analysis of moisture profiles at the deepest layer of the soil [30-100] for each site and a site to another emerges the following interpretations: The decrease in depth of moisture profiles is probably due to the decrease of the porosity. The MV1 site shows the highest profile and constitutes the wettest site. This pronounced water content can be explained by the steep downwards, which stimulates rainwater stagnation and percolation in there. There is the character of marl vertisols-vertices contributing to the stagnant water where high water holding capacity. Then, the BF site, located on the left bank near the wadi el GAMH, consists of raw mineral filler sols, which have low water retention. The moisture range of variation of the floor of the first layer is 20.83% lower compared to deeper layers because of the enlargement of the range of variation between the site moistened (MV2) and the site dry considered (BF). The spatial distribution of water contents on a date and at a given site depends on various factors, namely the type of soil, the previous crop, land use, etc.

-

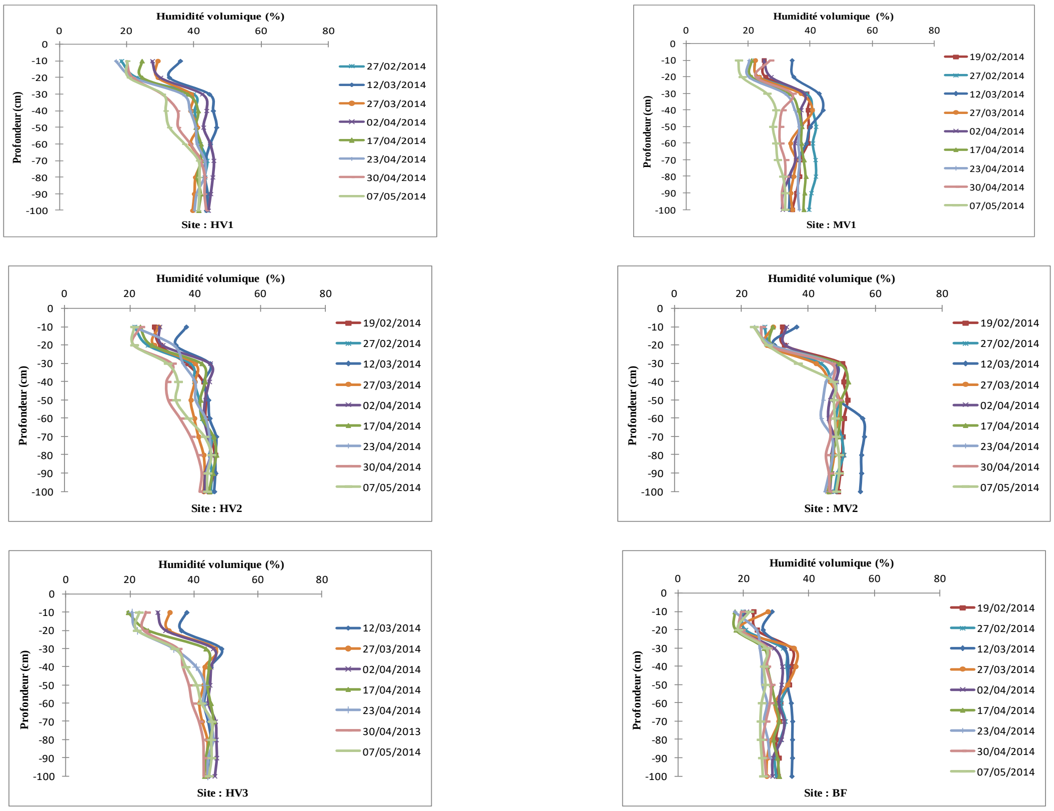


Figure 7. Spatial evolution of water profiles for different sites

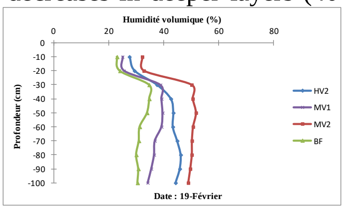
D. Temporal variability

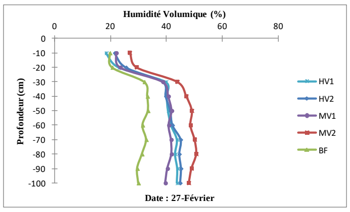
The profiles of the water content of the soil for the different measurement sites on the depth (0-100 cm) are shown in Figure 8. The graphs show that the water content of the soil increases with depth because of the strong influence of precipitation and flow between the active root zone and atmosphere.

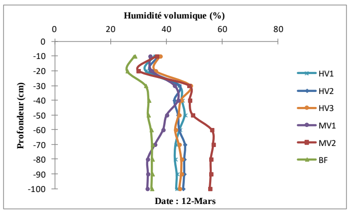
During the dry season (23-30 / 04 and 7/05), the average water content of the soil is 34.27%, with a minimum content value of 16.79% volumetric water and a maximum of 49 21%. During the wet season (19-27 / 02 and 12/03), the average water content of the soil has reached 39.18%, with a minimum value of the security content of 18.42% and a maximum of 56, 7% Hv.

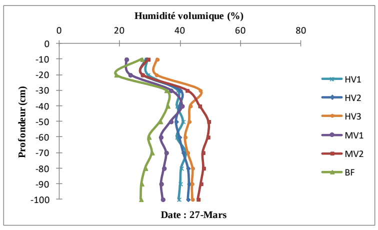
- The HV1 site changes between February 27 and March 12 shows that soil moisture Forgot 18.43% to 35.86% Hv. Three weeks later, the soil dries considerably, especially in the surface layers, to reach 24.48%. For this site, the deeper layers of the record levels exceed 40%. For the measurement made on March 12, this is explained by the high rainfall recorded between 5 and 10 March with two events of 21.6 mm and 8.8 mm, respectively.

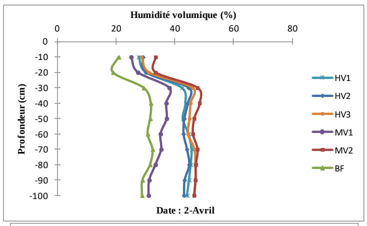
- The evolution of water moisture in the soil of the site HV2 is as follows: The water is quite significant stock in mid-February with the progressive availability of water by more layers deeper (greater than 50%). A week later, the moisture profile shows a drying out of the soil, especially in the first layers (almost 10% is lost in the first layer). The water content of the soil reaches 40.5% in the 30 cm depth following rainfall during this week. Then the soil dries out in the deep portion of the ground. During the following weeks, two dynamics are differentiated along with the profile, a dryness-rewetting of the soil due to rainfall inputs, evapotranspiration (accentuated by plowing done before). At the end of April, the soil is very dry (relative to other humidity recorded), then humidified the following week at the deep portion (30 to 100 cm) to which could be explained by dynamics shrinkage, cracks, clay, and capillary lifted from the ground.
- Going further down the slope at the site HV3 Specifically, progressive desiccation in time occurs on 12 March. The soil has a water content of 36% in the surface layer. This content increases to 48.6% in the layer (20-40 cm) and gradually decreases in deeper layers (40-60 cm), and then remains almost constant. The week after, the soil loses 5% moisture along with the profile mainly due to evaporation. The same for the next week, with the exception of a special operation in the deep portion of the floor where the humidity increases (from 30 cm depth). So on for far from (17/04) with a major loss of moisture in the surface layers that exceeds 10%.In the deep layer [60-100], curves condense, so the heart of the time variation of the water content in this layer is low.
- In siteMV1, at the surface layer [0-20], a volume average moisture there is 23.44% of which increases towards the deeper layers to a maximum of 38.06%. [20-30] a slight decrease in humidity is recorded, and then from 60 to 100 cm deep, light augmentation in settles. This fluctuation is mainly due to flow between the active root zone and the atmosphere since the surface layer is most exposed to change.
- In MV2 and BF, websites curves are very tight, especially at the deep layer; thus, changes in water content over time are not increased. For the site MV2, it declined by 5% between February 19 and April 2. Temporal variability in water content during the measurement period depends on climatic factors, namely rainfall and potential evapotranspiration.

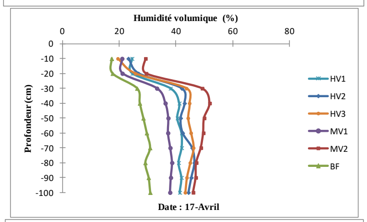


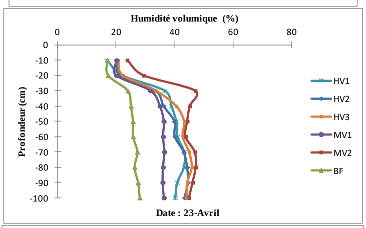


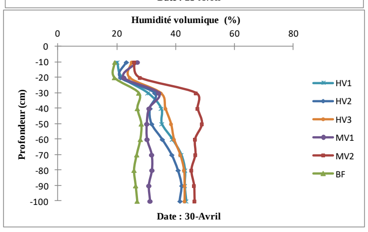












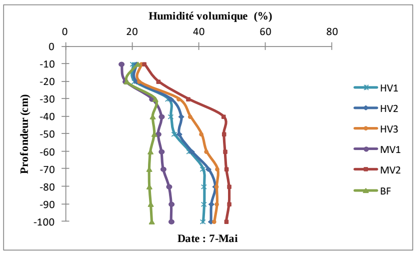


Figure8.Temporal evolution of water profiles for different sites

E. Spatiotemporal variations of water storage in the soil

a) Graph analysis

Following Figure9,the weekly change in accumulated stocks of water in the different sampling sites during the measuring campaign 19/02 to 07/05 on a 1 m deep. This variation is a marked fluctuation of stock between sites that is of the order of 254 mm in the BF and 476 mm in the MV2.At a very important weekly cumulative precipitation (64 mm) between 5 and 12 March, the soil at different sites culminated in a maximum water stock. The MV2 site is characterized by the largest water reserve, and its soil has stored 444.44 mm on average throughout the measurement period. The maximum water stock stored is 435 mm on February 19, and the minimum stock is 338 mm on May 7. This site has retained the maximum of its stock due to its steep slope that has allowed him to assemble run-off water and also the type of soil that is-magnesium hydromorphic kind.

The weekly stock remains roughly constant in MV1 sites HV1 and HV3 the site. At the latter, the stock varied slightly around 409 mm and reached a maximum around 437 mm and February 27, contrary to the site HV2 having a sharp fluctuation of the water stock. This is quite significant between 19 and 27 February and between 2 and 17 respectively reach 417 mm and 402 mm on average.

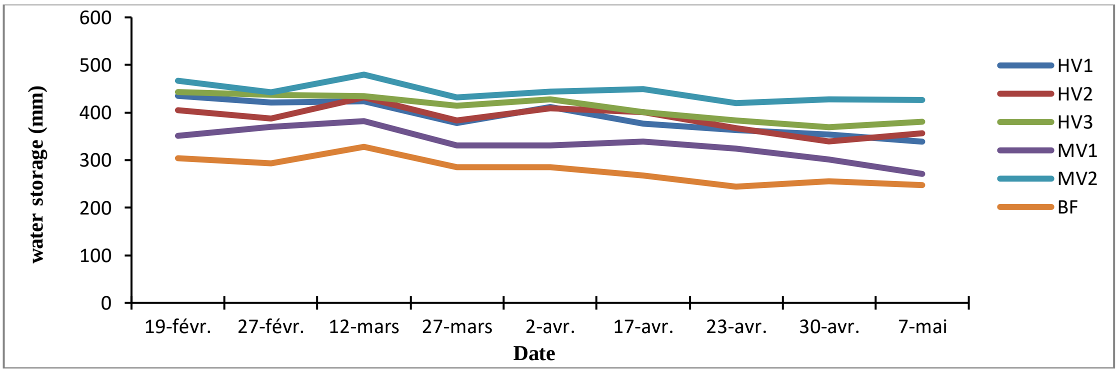


Figure 9. Evolution of water storage in the soil on 1 m deep

The following table shows the variation of water stocks (ΔS) at sites throughout the period of experimentation from (19 February until May 7). This variation is sharper at the site HV1, but it is minimal at the site MV2. Analysis of factors controlling the spatiotemporal variability of water reserves in the soil was pressing a statistical correlation study to identify different interpretations when the factors are controlling this variation.

Table 1. Water stored in the sites during the experimental period site

Site	HV1	HV2	HV3	MV1	MV2	BF
ΔS(mm)	96.23	48.02	62.41	79.39	40.12	56.23

b) Correlation between the main factors of water storage variability

Statistical analyzes were made taking into account the various factors: soil type, tillage, land use (occasion), the previous crop (PC), slope, exposure (Expo), and altitude (Alt). Table 2 shows that the type of soil, plowing, exposure, and altitude have no significant effect on the variability of water storage in the soil of the sites.

Table 2: Correlation matrix obtained from a parametric Spearman regression between soil water stocks and factors. ** p <0.05

	Stock	**Type of sol**	**Plowing**	**Land use**	**PC**	**Slope**	**Exposition**	**Altitude**
Stock	1,00							
Type of sol	- 0,21	1,00						
Plowing	-0,31	0,73	1,00					
Land use	**-0,36****	- 0,14	0,45	1,00				
PC	**-0,46****	0,82	0,95	0,28	1,00			
Slope	**0,48****	-0,22	0,30	0,40		1,00		
Exposition	-0,07	0,58	0,88	0,39	0,7	0,55	1,00	
Altitude	0,29	-0,94	-0,88	-0,13	-0,93	0,06	-0,66	1,00

The variance analysis shown in the following table shows that the variability of soil water stocks is partly explained by the position of the plots in the sequence topography and land use (10%, $p < 0.01$, and 46%, $p < 0.001$, respectively).This trend highlights the topographic effect visible in the landscape and the crops grown. So they seem to be a way of spatial water saturation of soils stocks.

Table 3: Results of the ANOVA on water stocks based on the effect of land uses and slopes. Coefficients of determination (R^2) degrees of freedom (.dll.) And significance (P).

Facteur de variation	**R^2**	**Dll.**	**p**
Land use	0.10	52	0.0198 *
Slope	0.46	52	1.02e-08 ***

Signif.codes:0 '***'0.001'**'0.01'*'

The spatial evolution of moisture profiles in the different measurement sites shows that the change in soil water reserves is mainly due to topographical factors: altitude, the position of the plot in the topographic profile, tilt the slope, and exposure, as well as land use. Volumetric water content varies between sites. For example, the soil moisture in the BF site is very low compared to that of the site MV2. [5]have explained that areas in the valley bottom, near the rivers and along the riverside, usually present surface humidities above those on the higher parts of the slopes. This statement explains the change in water storage between the two sites (MV2 and BF). Adds the slope factor and its exposure to contribute to the variation of the water distribution in the soil. For example, the site MV2, which is the moistest site, has a slope of 16% downward (direction of flow of the network), whereas the relief driest website (BF) is flat.[6]showed that the slope is the main factor responsible for the temporal variability of water storage in soil: the mechanisms responsible for this variability are firstly the redistribution of water in relation to the lateral base flow surface and sub-surface and secondly, the influence of the slope on evapotranspiration and condensation. According to [7], the slopes of steep inclines generally show the lower surface of the lower humidities tilt slopes.

This difference in water content can be further explained by the type of soil that differs from one site to another. High humidity Site MV2 is also explained by the nature of its vertical soil and especially its location near the water table. Two hypotheses can be retained when the dryness of the BF site: i) The previous crop is wheat which depletes soil water; ii) Rainfall differences between the lover and the approval of WATERSHED, in fact, studies conducted on this site after Mekki (2003) argue for that the presence of a rainfall gradient that decreases the ridge on the right bank overscale the left bank.

F. Mapping of the water storage in soil: spatialization Watershed scale

The two cards of the following figure show a heterogeneous spatial distribution of water stocks. This spatial distribution is marked by a deterioration in blue color to distinguish the different values of stock allocated to each area of the watershed. Five units were obtained. Arbitrary class 0 mm is assigned to areas where the rock is flush and the river system Lamech. In the areas in the valley floors, close to streams and troughs, water stocks are higher than those on the higher parts of the slopes. The figure 9 shows that the amount of water available to plants that can be stored in the catchment area is estimated at 988,893 m3 or about 7 times the storage capacity of Lake hilly in its construction (142,000 m^3). This result coincides with that derived by Mekki (2003) in his experiments on the same study site in 2001. This shows that the volume stored at the scale of the watershed is almost the same as the son for years. However, the amount of water available to plants that can be stored in the watershed during the dry season (water stress) is of the order of 855 339.74 m^3. This volume appears satisfactory. The table below shows the results.

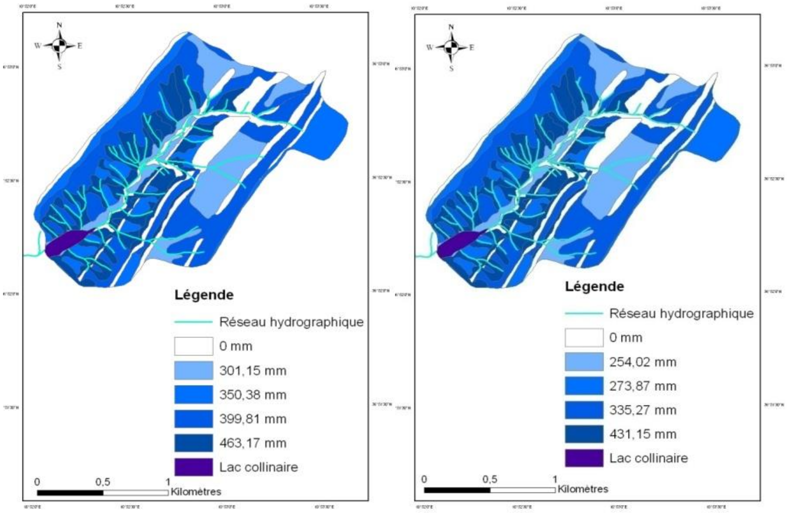


Figure 10. Spatial distribution of the water storage, February 19, 2014, and May 7, 2014

IV. CONCLUSIONS

This study is conducted on an agricultural watershed cultivated (250 ha) located north of Tunisia for a period that runs from 19 February to 7 May 2014. This work focused on the analysis of the spatial and temporal variability of soil humidity in order to quantify the water stock across the whole watershed and, therefore, a predictor of the development strategy for this distribution. For this measurement, six sites were chosen. The results show that the spatial and temporal distribution of the surface of the studied environment humidity is governed by several factors, namely i) climatic factors, i.e., rain as it is a culture system under rainfed and evaporation because the soil flows between the surface and atmosphere and ii) topographic and soil factors. The volume of water stored in the ground, which constitutes the water resource used by upland crops, has high variability in time and space. The results of statistical analyzes also showed a correlation of stocks of water with land use, the previous culture, and the slope. The analysis of variance showed that the variability of soil water stocks is explained in part by the plots of the position in the catena (10%) and land use (46%).

The result of water stocks associated with measured soil and topographic data integrated into a GIS has spatialized results across watershed and mapping of water stock across for two wet and dry seasons, a clear temporal and spatial heterogeneity of distribution of the water stock was deduced. This allowed us to assess the water quantity available to plants that can be stocked in the entire watershed total soil saturation. It is about one million m^{3,} estimated at 988,893 m^3, about 7 times the storage capacity of Lake hilly in its construction (142,000 m^3). Following this work, we can conclude that in terms of spatial analysis, larger mesh size and measurements of a higher number of scattered sites on both sides will be more effective. In terms of timing analysis, monitoring of the evolution of cultures is recommended to study the effect of vegetation at different stages of crop development on the variability of water stored in the soil. It also calculates the water needs of cultures, then an accurate assessment of water stokes available in the root zone. More that, this research study will serve for other applications to a broader scale. The precise knowledge of soil moisture and its spatiotemporal evolution is a key to monitoring the growth of vegetation, predicting agricultural production, improving water resources management as well as weather forecasts, and including better understanding the processes of water transfer in the soil.

REFERENCES

[1] Mekki, I., Analyse et modélisation de la variabilité des flux hydriques à l'échelle d'un bassin versant cultivé alimentant un lac collinaire du domaine semi-aride méditerranéen (Oued Kmech, Cap Bon, Tunisie), Sciences de la terre et de l'eau, thèse de doctorat, université Montpellier II, France, (2003) 173 .

[2] Allouche-Khebou, F., Éthologie du paysage : contribution à l'étude des changements d'états des paysages de la Dorsale Tunisienne et du Cap Bon, thèse de doctorat, Le Mirail, Ecole Doctorale de géographie de l'environnement, Université de Toulouse, France, (2007) 510 .

[3] Zante, P, Collinet, J &Pepin Y., Caractéristiques pédologiques et hydrométéorologiques du bassin versant de Kamech, Cap Bon, Tunisie. UMR LISAH IRD Tunis, DG ACTA Direction des Sols Tunis, INRGREF Tunis, (2005) 21 .

[4] Bacchi,O, Reichardt, K &Calvache, M., Les sondes à neutrons et à rayons gamma: leurs applications en agronomie, AIEA, VIENNE, N° 16, (2003) 71 .

[5] Henninger, J.L, Petersen, G.W, &Engman, E.T., Surface soil moisture within a watershed-variations, factors influencing, and relationship to surface runoff. Soil Science Society of America Journal, 40 (1976) 773-776.

[6] Mohanty, B.P, Skaggs, T.H &Famiglietti, J.S., Analysis and mapping of field scale soil moisture variability using high resolution, ground-based data during the Southern Great Plains 1997 (SGP97) Hydrology Experiment. Water resources research, (2000) 1023-1031.

[7] Moore, I.D, Burch, G.J & Mackenzie, D.H., Topographic effects on the distribution of surface water and the location of ephemeral gullies. Transaction of the ASAE. American Society of Agricultural Engineers, 31 (1998) 1098-1107.