CORRELATION ESTIMATION BETWEEN CEREALS HEIGHT AND INSAR COHERENCE: A CASE STUDY OF THE LEBNA WATERSHED IN CAP-BON, TUNISIA

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ABSTRACT

The aim of this paper is to estimate the correlation between wheat height and the Interferometric SAR coherence. This study will serve as a validation test to our previous work [1]. In this paper, we are testing the robustness of the use of the InSAR coherence as a parameter for wheat and barley growth monitoring in a special context humid to semi-arid climate and intensive agriculture. For experimental validation, the height of wheat crops was determined through the different phenological stage. In the same period of field campaign, twelve sentinel-1 images were acquired over the Lebna watershed. From these images interferometric coherence pairs were extracted and compared to the height variation of wheat and barley. Results showed a high correlation between height and interferometric coherence for the sites where the vegetation is dense (r=0.9). But when the soil component is important the correlation is weak (r=0.5).

Index Terms: Interferometric coherence, Sentinel-1, Wheat height, barley height.

1. INTRODUCTION

Cereals are strategic crops that ensure self-sufficiency and food security. Indeed, the monitoring of the biophysical parameters of this crop allows early detection of diseases and deficiency of this crop and yield estimation. the height of the crop is one of its biophysical parameters that allows the early detection of biotic and abiotic stress. Several methods and tools allow crop height monitoring among these tools include radar remote sensing. It was affirmed in ([2]; [3]; [4]; [1]) the radar data capacity for spatiotemporal monitoring of agro-ecosystems. Indeed, the acquisition of radars can be carried out at different phenological scale while offering a regular spatiotemporal monitoring. Interferometric Synthetic aperture radar is usually used for applications such as digital elevation map generation and studies of landslides. However, SAR interferometry can also be exploited in agricultural monitoring it could be used to improve the potentiality of SAR data. Several approaches are used to compute the relationship between this parameter and the crop height. The work of [5]

compares the height values with the interferometric coherence extracted from the ERS satellite acquisitions. Moreover, the studies of [6]; [7]; [8]; [9] used the INSAR coherence to deduce the height of crop. In this context, we investigated the relationship between cereals height (wheat and barley) and interferometric coherence throughout the phenological stages to validate our results in arid and semi-arid condition [1]. It consists to study the behavior of the coherence in two different contexts: low vegetation and rainfall < 200 mm for the previous test site we explored in [1], and for rainfall that can reach 500 mm and intensive agricultural region for the actual test site of Lebna watershed.

2. MATERIELS AND METHODS

2.1. Study area and ground data

The study area was the Lebna watershed (210 km², 36°43'N–36°53N; 10°40'E–10°58'E) located in the Nabeul Governorate on the Cap Bon Peninsula in northeastern Tunisia. In the watershed, the climate varies from humid at the top of jebel Abderrahmane, with precipitation above 700mm/year, to semi-arid over the eastern part, with rainfall below 500mm/year and annual evapotranspiration of the order of 1200 mm. The Lebna watershed is located in a region of intensive agriculture. Three wheat plots were set up in Henchir Turki, Sidi Hassoun and El Oudiane and a plot of barley in El Mida site (fig.1).

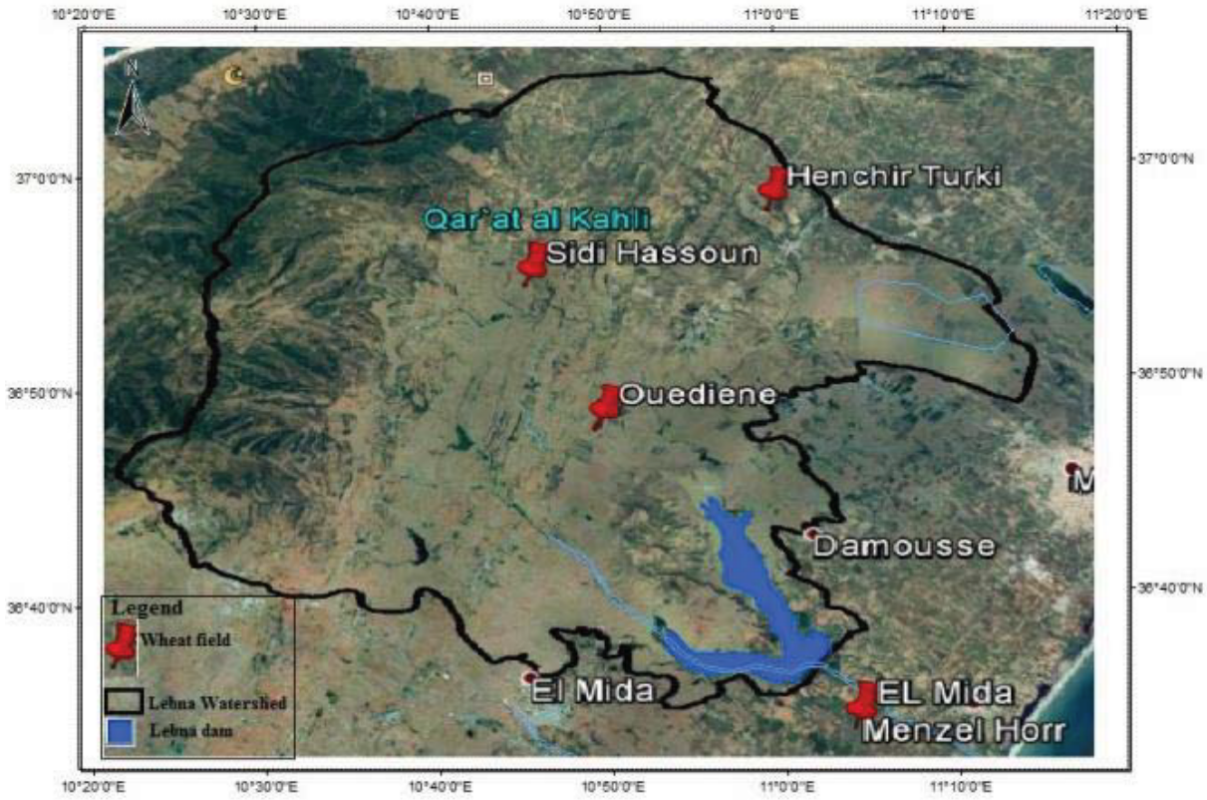

Fig1. Study test site location

2.2. Vegetation measurements

Planting was carried out on December, 2018. The harvest was carried out on July, 2019. Throughout the vegetative cycles of wheat and barley, measurements of height were performed for each test plot. For each stage, many measures covering each plot were randomly collected. All sampling points were located by geographical positioning system (GPS). The mean for each parcel was then calculated. Figure 2 illustrates the height measured in situ. crop height data reveals that the heights of the wheat and barley crop increase approximately linearly during the growing season.

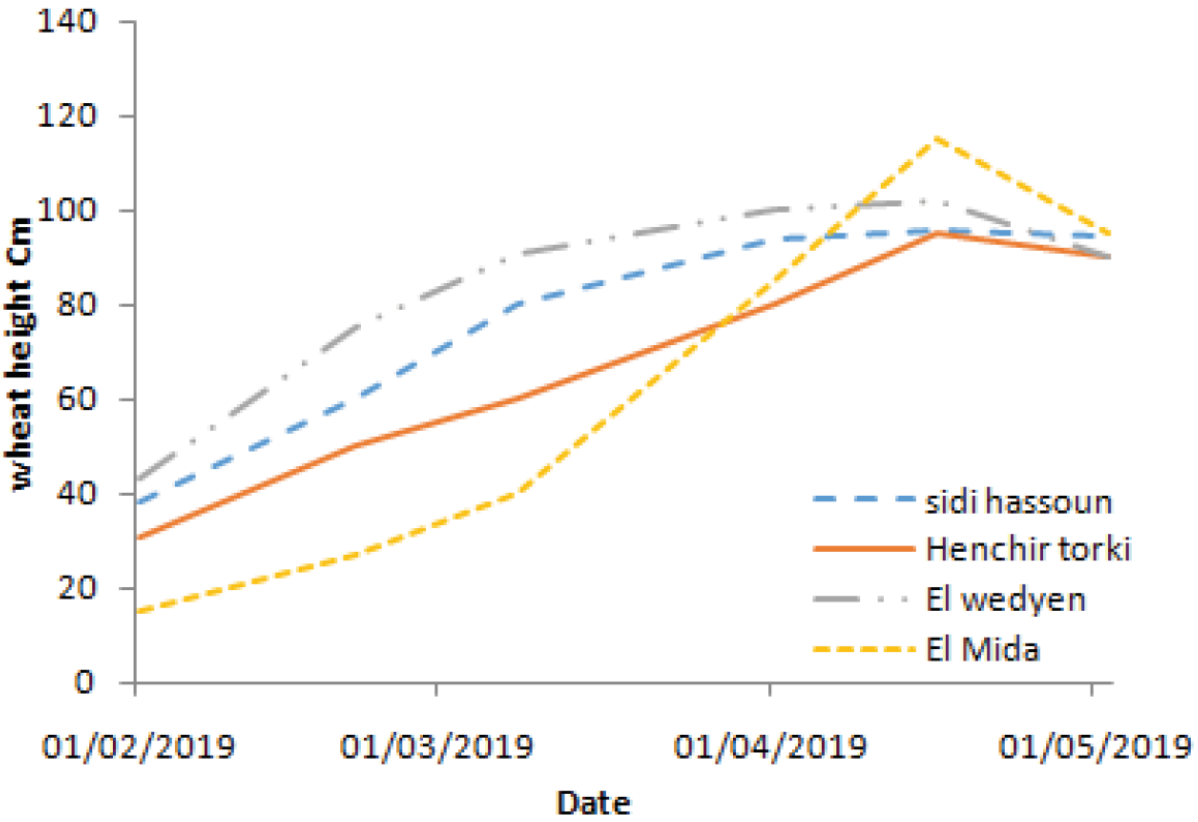

Fig 2. Wheat and barley heights variation

2.3. SAR image data

The SAR data used in this study consists of twelve images Sentinel-1 acquired during the period from January to May 2019. They were acquired in the interferometric wide swath mode (IW) with a 250 km swath at a spatial resolution of 5 m by 20 m. The data were acquired using vertical-vertical (VV) and vertical-horizontal (VH) polarization modes. These images were acquired during the same period with the ground measurement. The study focused on five pairs of images, from these images, we generated a coherence image for each of the deferent pairs and for each polarization (VH, VV) using the processing tools from the free and open access policy of the Geohazard Exploitation Platform and Portal (GEP).

2.4. Relationship between field measurement and SAR data

Considering the InSAR coherence image, we computed the empirical relationship between the height that was measured in situ and the relative averaged interferometric coherence considering the neighborhood of the correspondent pixel in the image.

3. RESULTS AND DISCUSSION

3.1. analysis of interferometric coherence

The coherence value ranges from 0 (total correlation) to 1 (perfectly correlated). A coherence map of the study area Lebna watershed is shown in Figure 3. The highest coherence value corresponds to Sidi Abderrahmane Mountain, whereas vegetated areas appear dark, showing lower coherence values. The majority of the area of this region is occupied by cereals and vegetable crops, which explains the low coherence results presented in the histogram (figure 4). The Sidi Bouzid region belongs to the arid and semi-arid bioclimatic stage and it is also characterized by an extensive cropping system based on arboriculture, grazing and dry cereals.

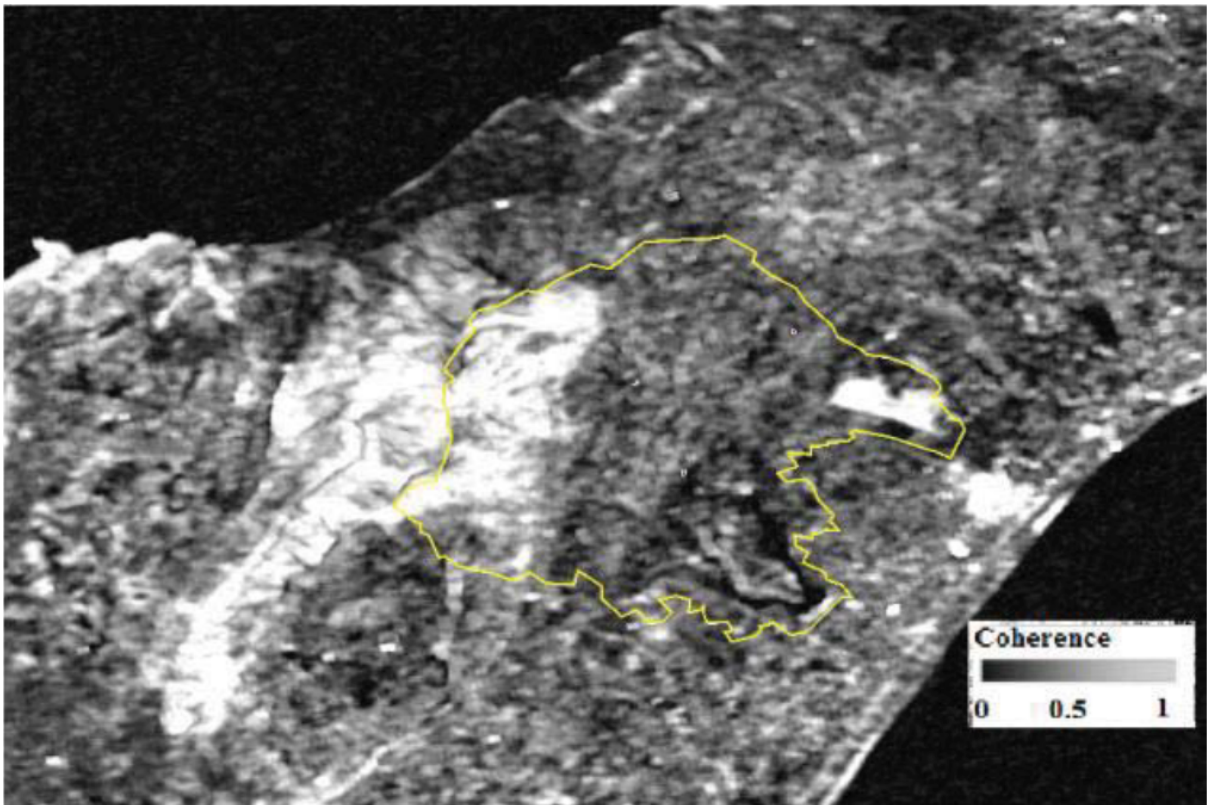

Fig 3. Coherence map of the Lebna watershed area April 13-April 19, 2019

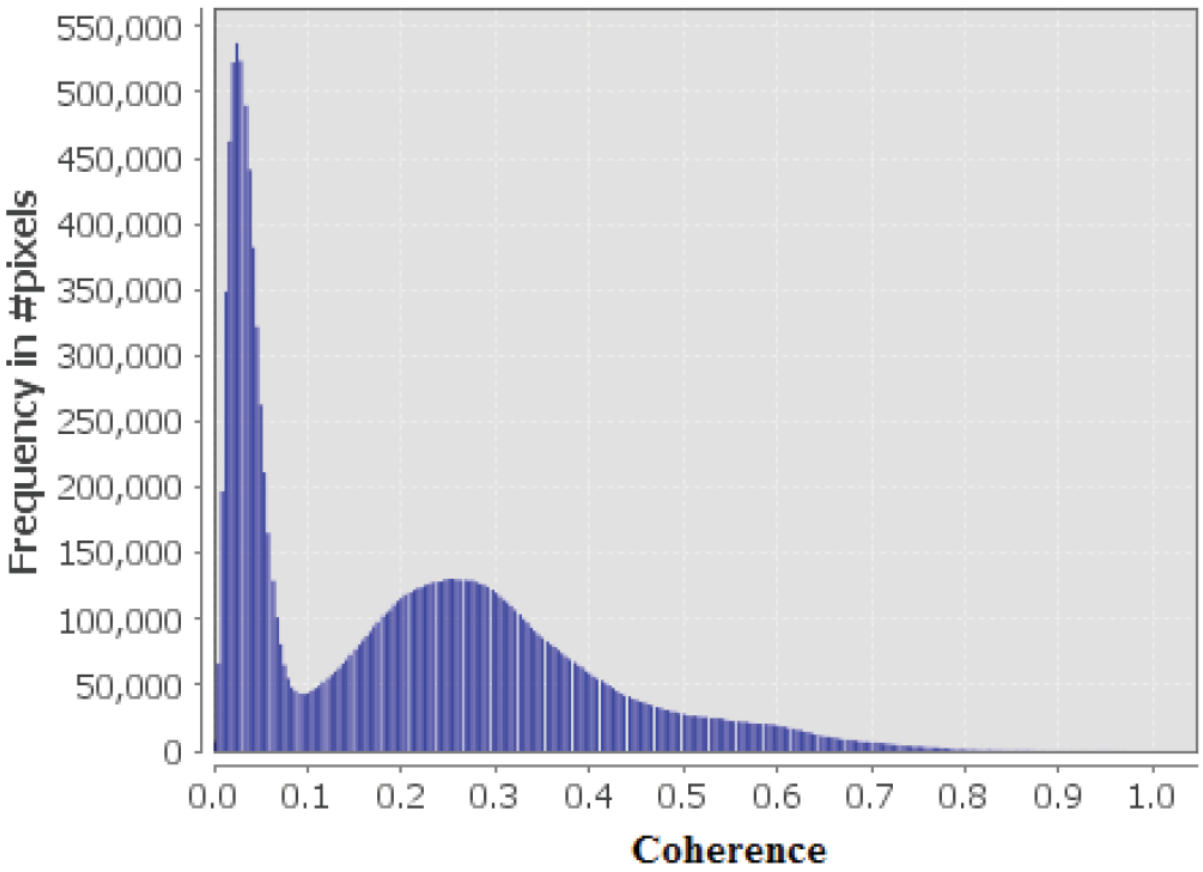

Fig 4. Coherence histogram of the Lebna watershed area April 13-April 19, 2019

The analysis of the coherence image of Sidi Bouzid (figure 5) shows that there is a difference in the values of the interferometric coherence in this region. Indeed, the coherence values in this region is higher (between 0.4 and 0.8) (figure 6).

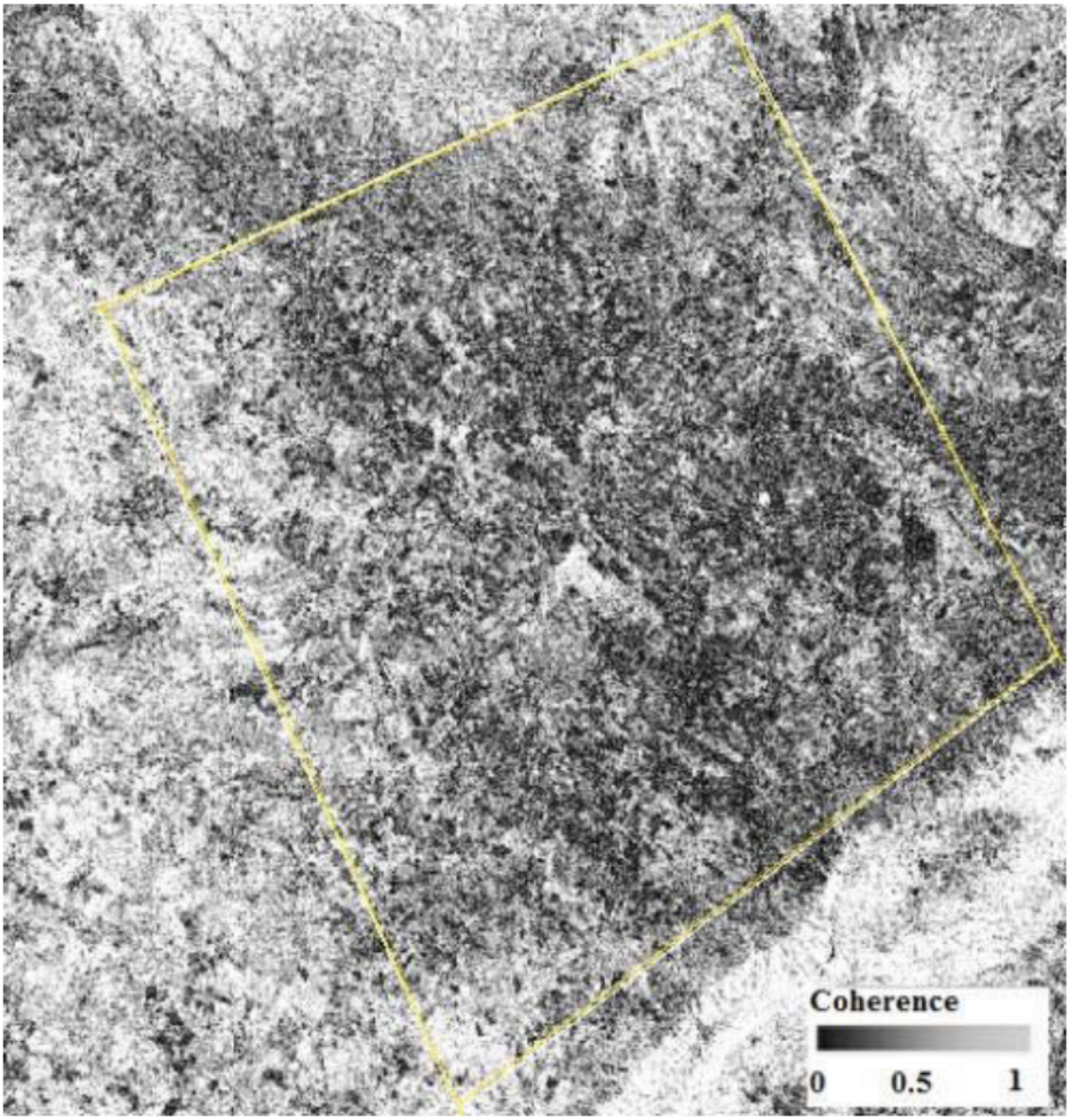

Fig 5. Coherence map of the Sidi Bouzid region April 03-April 15, 2016

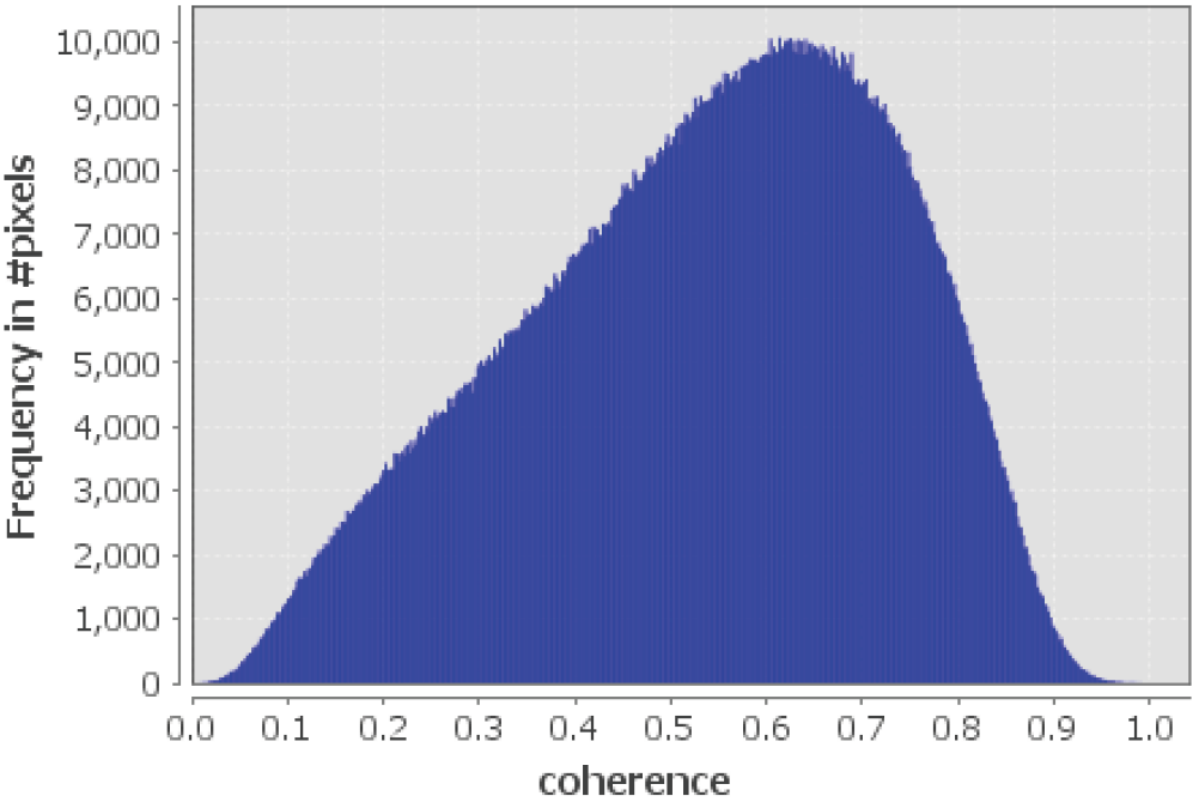

Fig 6. Coherence histogram of the Sidi Bouzid region April 03-April 15, 2016

Next, we perform a study of the effect of the region characteristics on the relationship between wheat and barley heights and the interferometric coherence by comparing these results with the results on the region of Sidi Bouzid that we published in [1].

3.2. Relationship between cereals height and interferometric coherence

Table 1 presents the correlation between wheat and barley heights and interferometric coherence. Considering the VH polarization we recorded a high negative correlation in El Oudiane and Sidi Hassoun sites this is explained by the high height values in these sites compared to other sites. Indeed, the height is high and the vegetation is dense and coherence is more sensitive to the density of crop cover in VH polarization. On the other hand, there is a higher variation of height for Sidi Hassoun and Oudiane wheat comparing to the other sites for example in the period between March, 8th and April, 1ththe variation of the wheat in Sidi Hassoun and Oudiane is respectively 20cm and 16cm. Therefore, when the variation of the vegetation is high the other source of variation can be omitted. The weak correlation for the other sites is explained by the intervention of an external factor that can cause a change such as the humidity of the soil, the roughness of the soil, the wind etc...

Cereal	Wheat			Barley
Sites	Henchirturki	Sidi hassoun	El oudiane	El Mida
Pearson correlation for VH	0.35	0.97	-0.84	-0.57
Pearson correlation for VV	0.64	0.24	-0.02	0.4

Table 1. Correlation between wheat height and interferometric coherence

For the barley, we recorded a weak correlation for the barley and Henchir Turki site because the height value is weak in the first stage so the soil component is important. If we eliminate the first stage (the period between February, 1 and February, 21) the correlation coefficient becomes significant for the four sites (table 2).

Cereal	Wheat			Barley
Sites	Henchir turki	Sidi hassoun	El oudiane	El Mida
Pearson correlation for VH	-0.58	0.99	-0.92	-0.71

Table 2. Correlation between wheat height and interferometric coherence without the first growth stage

Comparing these results with the results published on IGARSS 2018 [1], we found the correlation between wheat height and coherence in the Sidi Hassoun and El Oudiane sites is higher than the correlation in the Sidi Bouzid region (Table 3). This is explained by the vegetation density. Indeed, the precipitation rate in Sidi Bouzid is lower than 200mm/year so the soil is still visible even at the flowering stage. Therefore, the soil component intervenes in the coherence. That's why, in Sidi Bouzid the correlation value did not exceed the 0.6. On the other hand, in Lebna the rainfall is more intense and the coverage rate of the soil reaches 100% at the flowering stage so the intervention of the soil is minimal.

	Interferometric coherence
Rainfed wheat	-0.68
Irrigated wheat	-0.66

Table 3. Pearson correlation between wheat height and interferometric coherence in Sidi Bouzid region

4. CONCLUSION

In this paper, we aim to demonstrate the relationship between the heights of two cereals; wheat and barley and the interferometric coherence for Sentinel-1. Moreover, we aim to validate our previous study while changing climatic condition. We choose for this study case the north of Tunisia. The correlation between the height and the interferometric coherence reveals a correlation higher than those found in the context of Sidi Bouzid this is explained by the vegetation density. when the vegetation is dense, we eliminate the contribution of the soil component therefore the relationship between the height and the coherence is more significant.

5. REFERENCES

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