Contribution of the Radar Imagery in the Characterisation of the Dunes Morphology. Application to the Cordon of Zâafrane and El-Mesrane Regions (Djelfa, Algeria)

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Keywords: Geomorphology, image SAR and ETM+, morphology of dunes, mathematical morphology

SUMMARY

The objective of this work is to use the method of mathematical morphology for the characterization of the morphology of the dunes, of the cord of Zâafrane and El Mesrane of the wilaya of Djelfa.
Within this framework, a detailed attention is lent to the study of best filters and the statistical properties of Speckle on the radar image. We found the selection criteria most favorable, in the filter Frost (fenêtre3x3).

We were attracted by the "geographical" character of the approach of mathematical morphology. It makes it possible to carry out local analyses of the image favourable with the implementation of several notions such differentiation between the geometrical shapes of the dunes (Sif, Aklés), their dunes orientation and corridors or of deflation.

The applications on SAR image of amplitude give that the identification of dunaires forms is possible with the method of mathematical morphology. It supports the geometrical topic of the dunes of the dunaire cord of Djelfa.

RÉSUMÉ

L'objectif de ce travail est d'utiliser la méthode de la morphologie mathématique pour la caractérisation de la morphologie des dunes, du cordon de Zâafrane et El Mesrane de la wilaya de Djelfa.

Dans ce cadre, une attention particulière est prêtée à l'étude du meilleure filtre et les propriétés statistiques du Speckle sur l'image radar. Nous avons trouvé les critères de choix les plus favorables, dans le filtre Frost (fenêtre3x3).

Nous avons été attirés par le caractère "géographique" de l'approche de la morphologie mathématique. Elle permet de réaliser des analyses locales de l'image propices à la mise en application de plusieurs notions telles la différenciation entre les formes géométriques des dunes (Sif, Aklés), leur orientation et les couloirs inter-dunaires ou de déflation.

Les applications sur l'image SAR d'amplitude donnent que l'identification des formes dunaires est possible avec la méthode de la morphologie mathématique. Elle favorise le thème géométrique des dunes du cordon dunaire de Djelfa.

Mots-clés : géomorphologie, image SAR et ETM+, morphologie des dunes, morphologie mathématique

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1. INTRODUCTION

Between the typical Mediterranean landscapes of Tell and the Saharan desert, the Algerian steppes occupy a quite particular hinge position. In these areas, the climate is austere, very hot in summer, often very cold in winter, supporting a chronic dryness.

In this work, we will use the teledetection, which plays an important role for the characterization of surface properties. The most used bands are those of the microwaves. This band will be used by satellite ERS2, the data are dated from the 19/06/2000.

In order to characterize the morphology of the dunes occupying the dunaire cord of Djelfa "the zone of Zâafrane and El Mesrane", we use new morphological methods allowing to extract morphological characteristics from the dunes shown in the radar image (ERS2). This consists on differentiating the forms according to geometrical properties' from the radar image, by the mathematical morphology method.

1.1 Characteristic of the Study Zone

Between Zahrez and the Saharian Atlas, the dunaire cord is intercalated with an extension in a direction from South-west to North including two wilayas (Djelfa and Me sila). Its lenght is about 250 km , from Oued Touil to Djebels in the East Zahrez Chergui, and approximatively of 3 to 5 km width **[1]**. Active dunes , of rather badly defined forms, reach sometimes the 20 meters height. The dunes shape depends on dominant winds. Sandy dunes can sometimes be found lengthened on many hundred kilometres; tangent with an obstacle wake. During storms, sand migrates along the dune, parallel to the building which lengthens according to its own direction (Mainguet, 1983). The profile is formed by two running sand slopes strongly inclined, being cut again in an active peak.

Initially composed of small insulated solid dunaires masses , the dunaire cord becomes slowly continuous and hardly passable. The less high dunes relatively allow the installation of a psammophile vegetation (Tamarix, sp. Phragmites communis, Aristida pungens) **[2]**.

We've chosen for our study the area of Zâafrane and El Mesrane. This zone is part of the of Algiers southern steppe (300Km in the south of Algiers), in the basin of Zahrez Gharbi which is a semi-arid zone limited between longitude 2°50 ' to 3°05 ' Est and the latitude of 34° 45 ' to 34°55' 12 North. It is limited to the North by Zahrez El Gharbi and to the south by a

mountainous system of Djebel Sahari (cf Fig.1). Dunes invasion is considered as the major danger due to the wind effect; it is essential to know their dynamic in order to be able to quantify different types of represented danger. To make the answer clearer, we suggest a classification of dunes according to different parameters' which manage their dynamic **[3]**:

- *Trapping dunes of the wind particles by a plant:*
- · Nebkas and rebdous;
- *Intermediate dunes between transport and deposit:*
- · Linear dunes (sifs),
- · Barkhanes and buildings barkhanic.
- *Dunes of deposit:*
- · crossed buildings: barkhnic chains and transverse chains, when sand is available in abundance.
- · Pyramidal dunes (ghourds),

- *Dunes of erosion:* longitudinal dunes and parabolic dunes.

2. WORK METHODOLOGY

Among the numerous methods allowing to carry out the functions of simplification and extraction starting from the images on the level of grey; methods of mathematical morphology **[4]** seem particularly adapted in our study: They enable us to gradually structure the image according to relevant morphological criteria's (Mering and Jaqueminet, 1987 **[5]).**

Our objective is to delimit starting from an image in colour of grey and another binary, entities of forms thematically significant. Thus, this approach can be comparable with a computer-assisted photo-interpretation.

The dunaire cord of Djelfa has a continuous cover organized in alignments of large domes separated by corridors where deflation dominates: The homogeneity of the substrate makes a spectral approach difficult. An automatic cartography of domes and surfaces of deflation will be carried out starting from the methods of mathematical morphology by developing a sequence of operations.

The filtered radar image will be treated in colour of grey to homogenize the various surfaces then binarized after contours will be smoothed.

The determination of the classification of dunaires forms is obtained starting from the work already completed on scenes SPOT (051-280) on the 30/06/88 and their evolution to the 23/06/98 in collaboration with field work.
Because of the very different nature of these images, the problems to be solved are, in a first stage, the filtering of the radar image infected by a multiplicative noise called "***speckle***", secondly, the application of mathematical morphology **[6]** and **[7]**.

3. MATHEMATICAL MORPHOLOGY METHOD

3.1 Choice of the image of treatment

In order to differentiate the great forms of the dunes we used the image SAR which is characterized by the space resolution 12.5X12.5m. It is treated by the adaptive filter Frost (window 3x3 only one iteration) in order to minimize the speckle. This SAR image generally shows dispersed sets, lengthened with different texture. Our methodology of treatment aims at individualizing each one of these sets **[8]**.

Aklés occupying domes of the cord are of very small dimensions. Their lit faces with high spectral answer never constitute one element of the pixel of the image Landsat ETM+ (30X30m), which always comprises elements in the shade. With a such resolution dunes forms cannot be differentiated. A reduction of its from results with the opposition between the surfaces from aklés and the surfaces of deflation making treatments used ineffective.
Therefore, the resolution of SAR image as its mode of sight catch are the essential factors to support the detection of different dunaire forms on the cord and the plane zones surrounding the dome.

3.2 Principle of the Morphological Filters used on SAR Images in Grey Levels

The morphological transformations on SAR image are generalized in levels of grey as the following way: A function f(x) is considered.

For each point it is necessary to associate an element structuring B In the field defined by B around X, f(x) has a higher value and a lower value.
To build the function *eroded* by an element structuring B, it is enough to allot in each point of the field B_X (*i.e* the element B centered as in point X) the value lower than takes f(x) in this field **[9]**.

$$\mathrm{E}^{\mathrm{B}} f(x) = \inf\{ f(u) : u \in B_x \}$$

In the same way, to build the function *dilated* by an element structuring B, it is enough to allot in each point of the Bx field the value higher than takes f(x) in this field **[9]**.

$$\mathrm{D}^{\mathrm{B}} f(x) = \sup\{ f(u) : u \in B_x \}$$

If a graph is compared to a relief, one will say that *erosion* reduces the "peaks" and widens the "valleys", whereas *dilation* thickens the "peaks" and roof the "valleys". *The opening* Bfr and *closing* morphological Bfrs of a function F will be defined in the same way, by analogy with ensemblists transformations **[9]**.

$$f_B(x) = D^B\left(E^B f(x)\right)$$
$$f^B(x) = E^B\left(D^B f(x)\right)$$

These transformations modify the image at the level of grey only in certain points:*the opening* shaves the sharp-edged peaks and *closing* fills the narrow valleys of the relief.

The properties of these transformations will be used to define morphological filters such as *the top hats*.

- · The hydrographic network is distinguished by a dark colour and narrow ,and for the troughs, the dark zones are broader with the transformation *hat high form* (cf Fig.2).
- · Alignments of the sifs highlighted with a widening of the dark zones by *a dilation* of size 1 (Cf. Fig.3).
- · The hydrographic network is distinguished on the image by *an erosion* from size 1 as well as Aklés dispersed on the cord and the glacis (cf Fig.4).
- · Delimitation of the various dunaire sectors of the dunaire cord by *an opening* of size 1 (cf Fig.5).
- The zones of deflations or the corridors between the dunes are highlighted by *a closing* of size 1 (cf Fig.6)

3.3 Analysis of Results

On SAR image at levels of gray treated by the filter Frost **[10]**, the levels of grey sufficiently homogeneous and they are differentiated to make it possible to delimit the required sets:

- The sectors of deflations are deduced from the delimitation of the pale zones which correspond to the pointed dunes. Their forms are sets complementary to the pointed dunes.
- Aklés have a characteristic texture, consisting of the alternation of enlightened faces of sifs and darker surfaces.
- This texture which not only allowed the description of large domes, but also, levels of grey of the sifs facing the sun which is very high. Their detection is possible by the application of a transformation *top hat* from an opening of size 1 (cf fig. n° 2).
- Clear zones surrounded by dark zones are the tops of dunes and their slopes. A dilation highlights dark zones which are the troughs. The resulting unit is larger than the sectors which really exist in the field.

3.4 Principle of the Morphological Transformations Used on Binary SAR Image

On the radar image, we have to detect one or more forms on the bottom we apply a simple method using in an exclusive way of radiometric information.

The threshold makes it possible to extract "a category of objects" in the form of a binary image which we can simplify contours. On the radar image already filtered, the only values of the pixels after threshold are 0 and 1 **[8]**.

The digital image analyzed in this study is a binary image which results from the threshold of SAR image in levels of grey.The purpose of this threshold is to obtain an image which corresponds only to the surfaces of deflations, another with the sifs of domes and another with aklés which occupy them. After an examination on screen we combined the three threshold images then we applied the filters of mathematical morphology.

Thus, the unit defined on an image corresponding to a single value of the threshold or a single class. Classes of threshold used are (cf fig. 7):

- · ***from 0 to 85:****sectors of strong deflations and between dunes corridors (on the image in white).*
- · ***from 0 to 361:****sectors of Sifs (on the image in blue).*
- · ***from 0 to 721:****sectors of Aklé (on the image in black).*

3.4.1 Recall of the binary theory of transformation

In Mathematical Morphology, the definition is that of the set theory. The morphological analysis of a unit X is carried out via transformations ensemblists into all or nothing:X (X)

These transformations operate using a structuring element (which will be called simple B) of geometry such as: the circle, the segment, the hexagon. B is moved so that its center *X* occupies all the positions of Euclidean space. For each position, one checks if B and X check a certain type of relation ensemblist, this relation being expressed in term of union, intersection or inclusion. The result of this checking is expressed by a positive or negative answer, from where the name of transformation into all or nothing.

Transformations of the opening and closing make it possible to structure the image by simplifying contours of objects but without modifying in a significant way their geometry nor their size. However in certain cases, it is simply a question "of cleaning a unit", i.e. to eliminate the small related components while preserving contours completely from the largest related components **[8]**.

3.4.2 Element structuring on square and hexagonal grids

According to the image (matrix) and the convex element structuring, the transformation can be different because the origin from the image agrees to a grid. Therefore, one used the square grid (window 5x5), for the image processing radar.

3.4.3 Results on the binary image

The application of *dilation* allowed us to the identification of the between the dunes corridors and the dunaires buildings appearing in luminous distinct meshes(Cf well. Fig.8).
Erosion, implies the disappearance of the sifs on the dunaire cord and a good dispersion of aklés on the dome and the plane surface around this last which probably corresponds to the barkhanes. The filter of erosion highlights the limit of Zahrez as well as the waves of the hydrographic network (cf Fig.9).

By the execution of *a closing* appear very distinct alignments from the sifs like their orientations SW/NE as well as deflations (corridors between the dunes) and the scraps of sandy accumulations around the domes of the cord (cf Fig.10).
The opening distinguishes the density of aklés compared to the sifs especially in the first dunaire sector just as the limit from Zahrez (cf Fig.11).

The execution of *a top hat* brings to our analysis a comparison between the direction of dominant winds and the direct observation on images treated by mathematical morphology, this highlights the principal orientation of the domes is WSW/NE which are clearly shown(Cf. Fig.12).

4. CONCLUSION

The space and spectral resolution supports, in particular, the use of the method of mathematical morphology on already filtered SAR image the Frost filter.
The application of the filters of mathematical morphology, on binarized image SAR, gives that the transformations of erosion and dilation make it possible to structure the image by simplifying contours of the objects, but without modifying in a significant way their geometry nor their size.

However in certain cases, it is simply a question "of cleaning a unit", i.e., to eliminate small related components while preserving contours completely from the largest related components.

On SAR image in several levels of grey, deflation sectors are deduced from the delimitation of the pale zones which correspond to the pointed dunes. Their forms are set complementary to the pointed dunes.

Aklés have a characteristic texture, consisted on the alternation of enlightened faces of sifs and darker surfaces.

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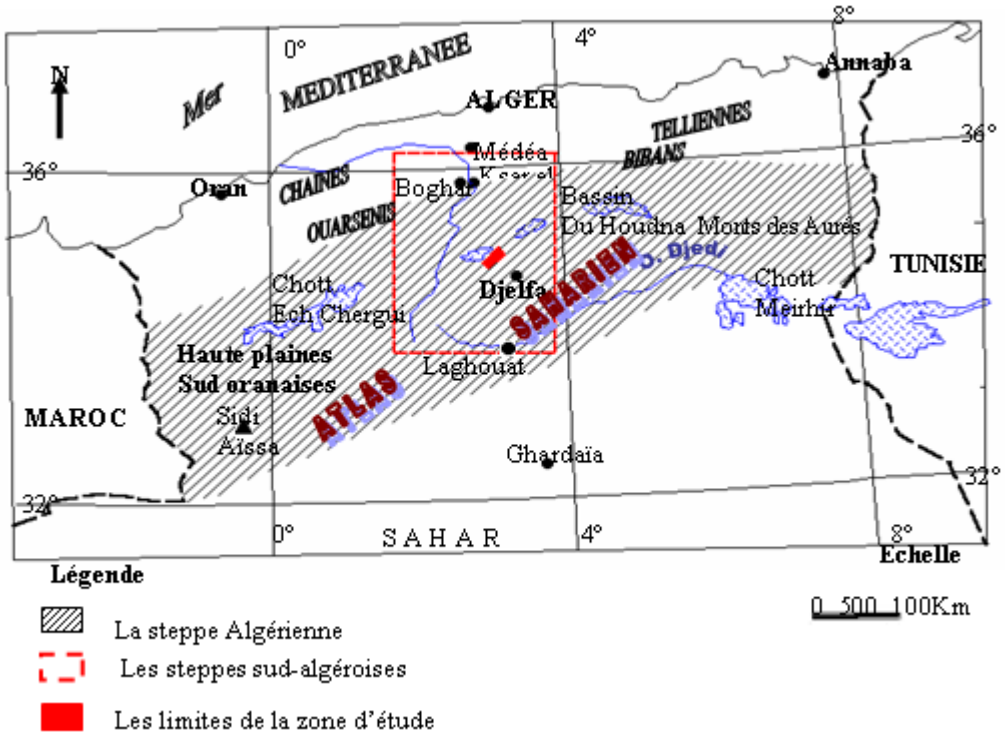

Fig.1: Sketch of localization of the zone of study.

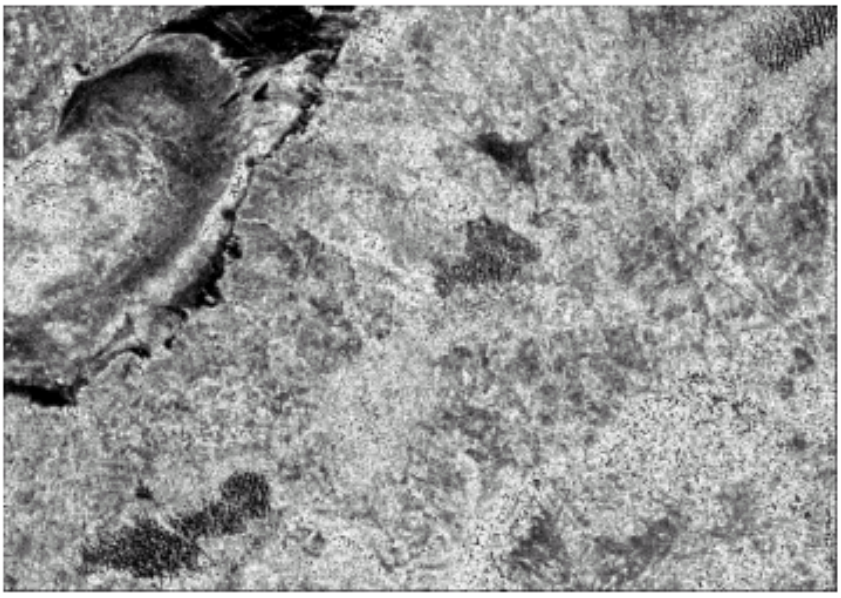

Fig. 2: Application of the transformation top hat on image SAR.

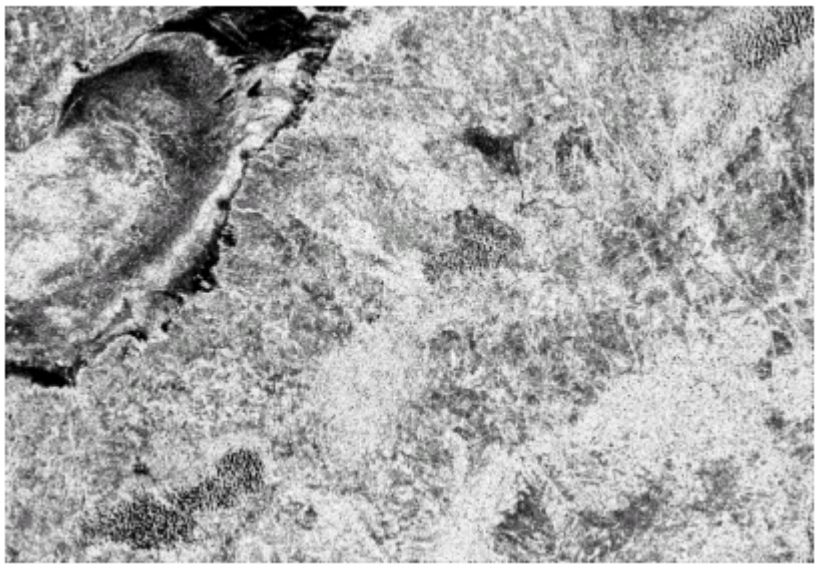

Fig.3: Application of the morphological parameter dilation on image SAR.

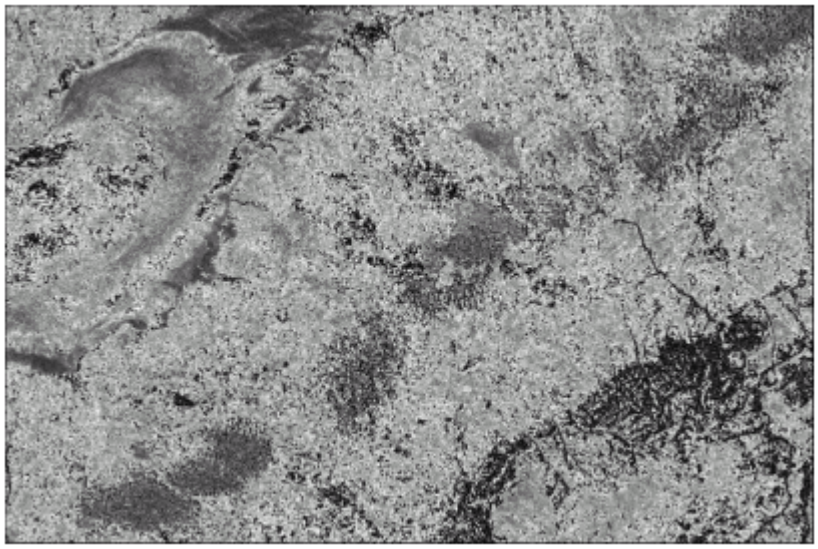

Fig.4: Application of the morphological parameter erosion on image SAR.

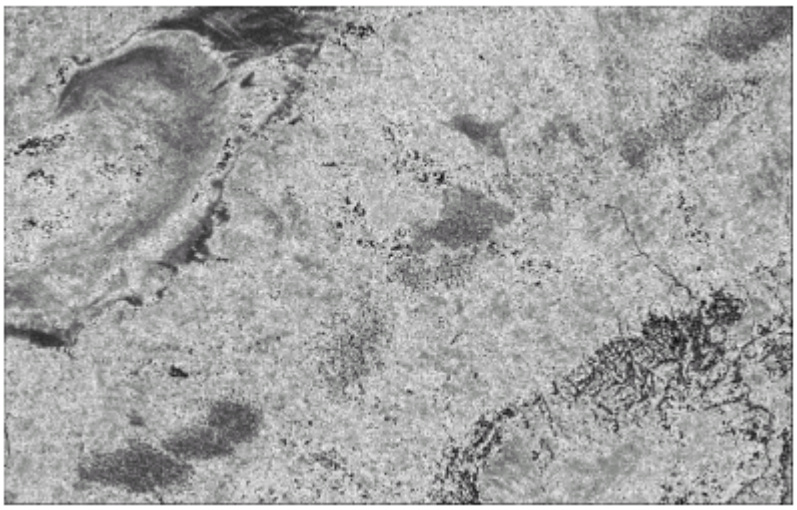

Fig.5: Application of the morphological parameter of the opening on image SAR.

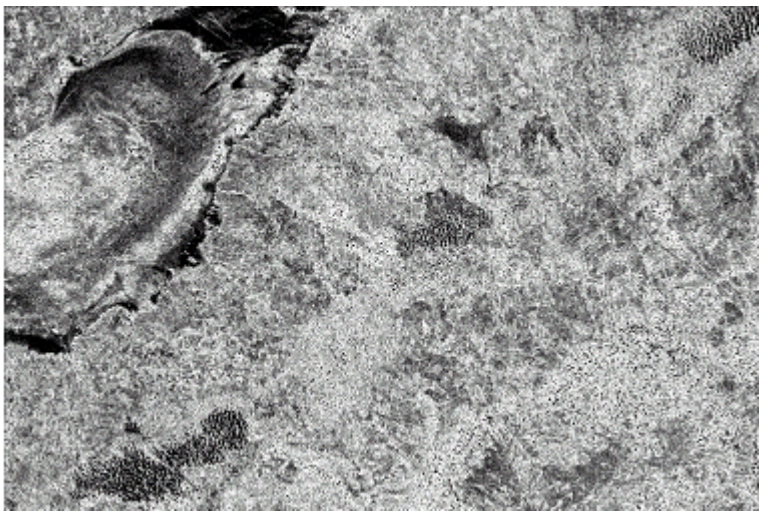

Fig.6**:** Application of the morphological parameter of closing on image SAR.

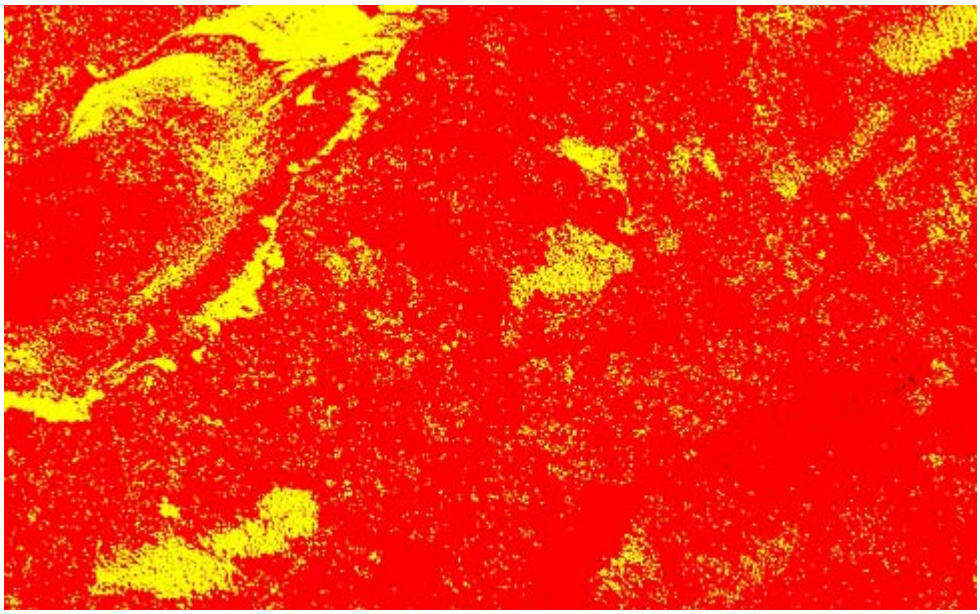

Fig.7:application of dilation on different the sector dunaires from the cord of Djelfa.

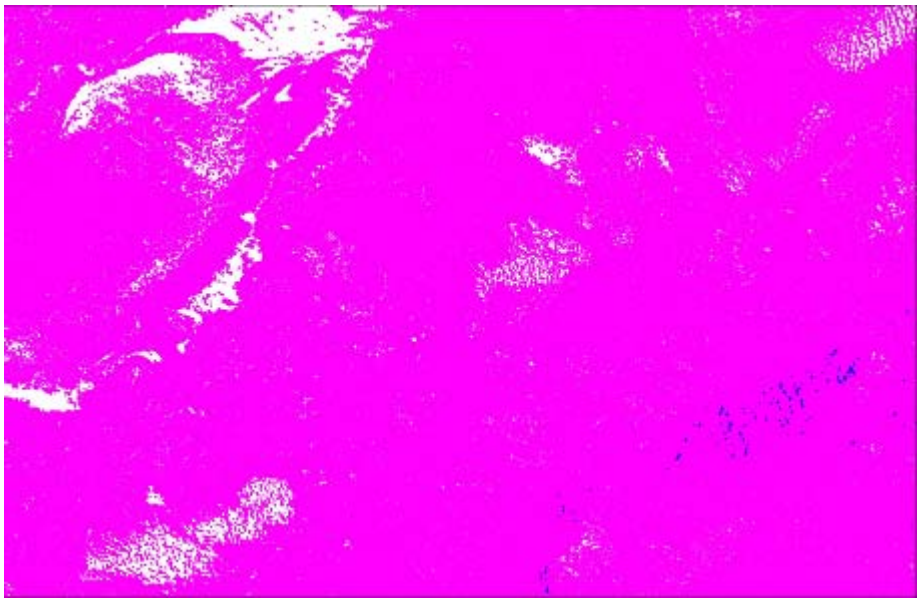

Fig.8:application of erosion on different the sector dunaires from the cord of Djelfa.

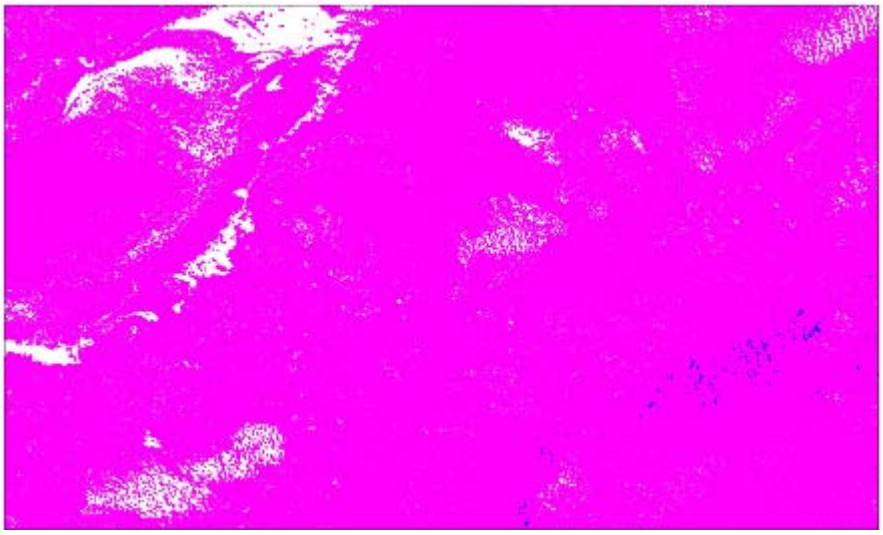

Fig. 9:application of closing on different the sector dunaires from the cord of Djelfa.

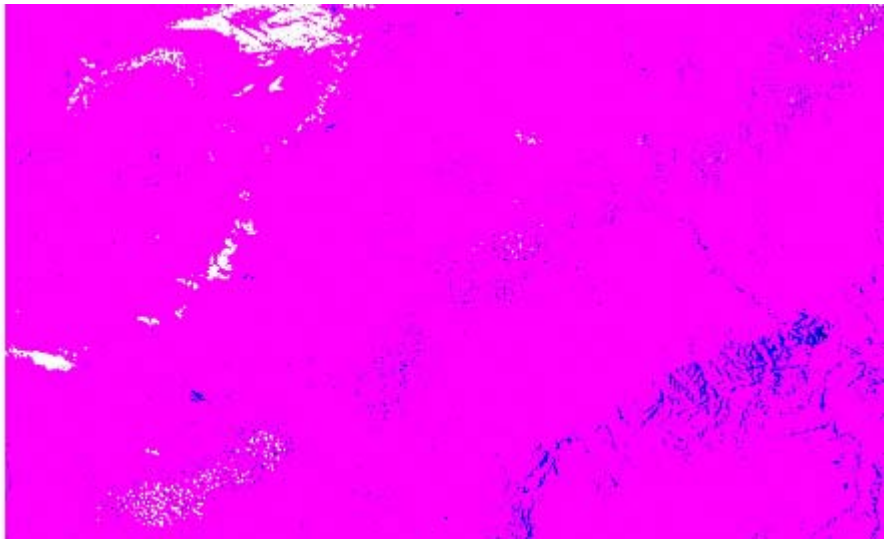

Fig.10**:**application of the opening on different the sector dunaires from the cord of Djelfa.

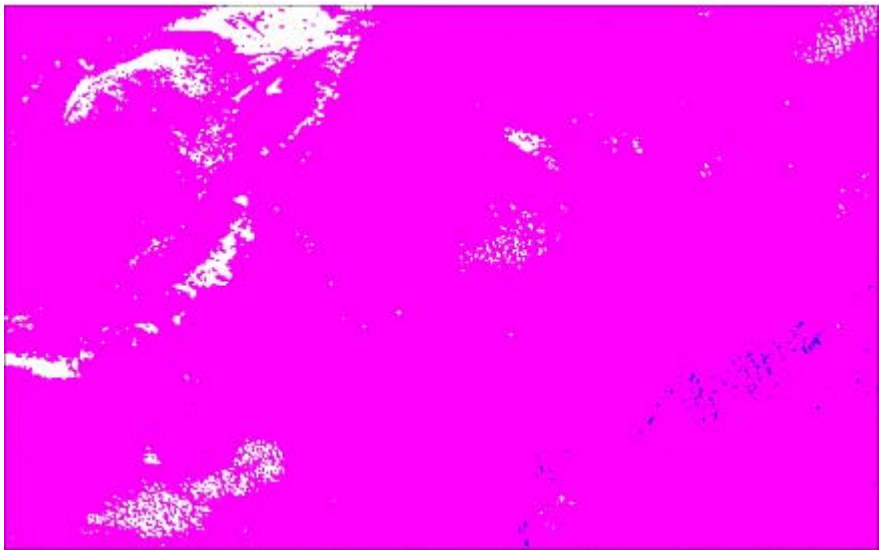

Fig.11**:**application of the filter top hat on different the sector dunaires from the cord of Djelfa.

BIOGRAPHICAL NOTES

Academic experience: PhD Student at University of Oran (Algeria) : 2005 – until now.
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