THE EVOLUTION STUDY OF THE NATURAL HAZARD ZONES BY THE KOHONEN SELF-ORGANISING MAP CLASSIFICATION

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ABSTRACT:

This article consists to explain the application of a semi automatic and multi temporal method of classification of the spot images. The objective is to follow the evolution of the units of landscapes factors of risk in the Nouakchott area (in West Africa). In fact, it was proved in the literature of image processing techniques and remote sensing, that there is not a completely automatic method of classification, considering the complexity of the phenomena represented by a pixel and the geometrical resolution of this same pixel. The method used in this work allows the intervention of the expert (of validation) in certain stages of the application. The goal is to improve the results of classification without repeating all the calculation.

We applied the method to chart the landscapes units of the environment of Nouakchott. The objective is to monitor the environmental hazards in this region characterizing the classes corresponding to landscape units present in SPOT images and to survey their temporal evolution. The method consists to apply the Kohonen Self-Organizing Map (SOM) algorithm on a data base of multi-dates images. The obtained Kohonen topological map is constituted of 100 neurons. Each neuron represents the reflectance spectrum of a subset of the training database. This map is thus representative of all the units of landscape present in the images of various dates. A Hierarchic Ascending Classification (HAC), with number of classes, is applied on the topological map to aggregate the subsets presenting similar reflectance, therefore to group all the local variability of the landscape.

The classes gathering the 100 calculated subsets are labelled to make the correspondence of a given class to a landscape unit on the ground. These units present the factors element of risk. Once the map is validated, for each date, the image is classified automatically by a simple assignment of its pixels to the nearest neuron of the topological map. We thus obtain a series of classified images from the same map, what allows one to quantify the evolution of each class compared to its counterpart of other dates, and therefore to evaluate the risks evolution .

1. INTRODUCTION.

Nouakchott is a sahelian city located on the Western side of the Atlantic (18°4 ' N, and 15°58 ' W).it's populated moreover than one million inhabitants, the growth rate of its population has increased more and more since ten year (according to Weicheng, Wu., Courel, Le Rhun, J., 2003). These districts are threatened by two principal types of risks. The floods coming from the Atlantic Ocean on the Western side and the stranding due to the deposit of new dune in the East. The evaluation of these risks is carried out by a diachronic monitoring of the units of landscape constituting the environment of this area.

The town of Nouakchott is separated from the sea by a thin coastal dune, behind which the lagoon of Aftout Esaheli. Its districts are encircled by the zones of the salted water of lagoon in the West and by the great dunal sets in the East (Eluard, P). This particular situation exposes the city and his environment to big geomorphological changes (Weicheng, Wu., Courel, M.F., Le Rhun, J., 2000) and two types of major risks.

The risk of flood coming from marine water trace in particular the Western and North-western districts of Nouakchott, these districts being established in a topographic depression compared to the level of the ocean. Indeed these districts already underwent several situations of flood of which most significant is that of December 1997 and then that of June 2000 which required the moving of several districts (Haag, M., 1998)

The three factors of this risk (Courel, M.F., Leterrier, E., Le Rhun, J., 1998) are, wind erosion, tablecloth salted water resurgence on the level of the lagoon, the rains, and the rupture of coastal dune inducing the water marine intrusion (Giresse, P., 2000). The stranding constitutes the second major risk threatening Nouakchott.

It acts especially on the East and South-east districts, as well as the road network of this part of the city. This phenomenon is due to the degradation of the dunes vegetation of Amoukrouz, consecutive with the drying-out of the area since 1968, which caused the remobilisation of sands and the appearance of sharp dunes (Courel, M.F., Bicheron, P., Mougin, E., 2000), so much at the top of the dunes than in the inters dunes.

To monitor the evolution of the risks we proceed by the multi temporal study of all the landscape units constituting the environment of the area of Nouakchott. We can gather these units in two great parts, the marine and the continental part.
For the flood risk the marine units of landscape to direct influence on the coast are shore-face, the zone of breaking of waves and the bottom of beach.In the continental part along the beach, the units of landscape undergoing the floods are, the coastal dunes (fine and dry white sand compound), the lagoon (compact wetland argillaceous ground), often flooded because

of the ruptures of the coastal dunes, nouakchotian area (composed of gypsum and shells) witch facilitates the resurgence of the salted sheet of water. See the profile shown in Figure 1 (Elouard, P., Faure, H., 1972).
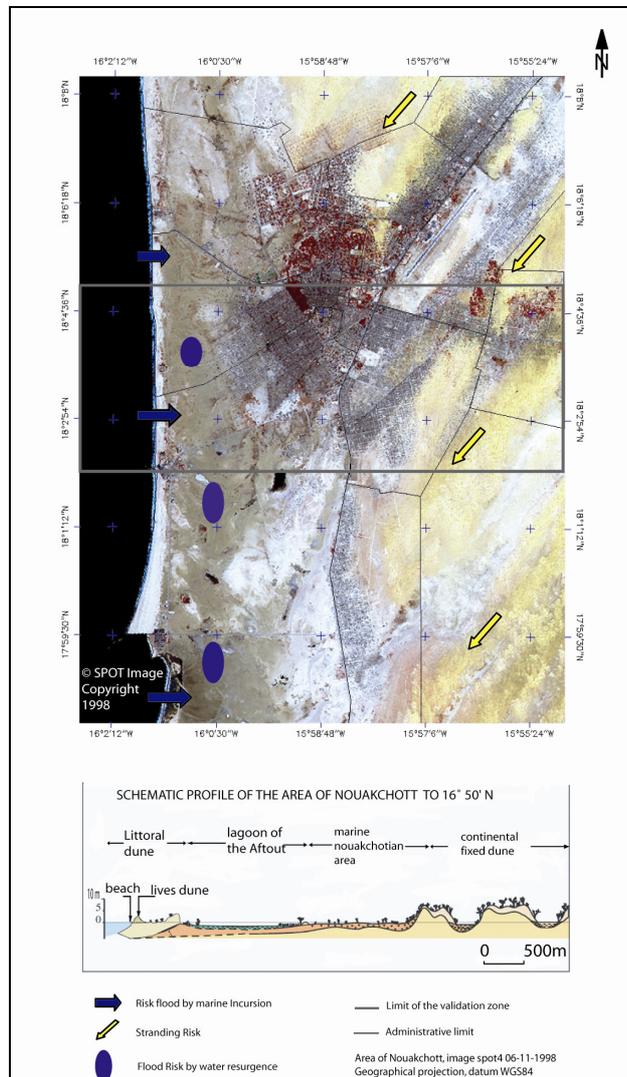

Figure 1. Context and factors of risk on Nouakchott

the most significant landscape unit, concerned by the risk, is the urban zone classified in three categories, dense, less dense and dispersed.

For the risk of stranding, the landscape unit factors of this risk are in the East of the city, it acts of the old dune (red dunes composed of organic materials of the quaternary period), the ergs (large wind dunes) and of the dunes sharp.

2.   THE SELF ORGANISING MAP OF KOHONEN

In the Self Organising Map of Kohonen model (SOM) (Kohonen, T., 1984) the map is a square grid of 10*10 cells. The SOM model allows to partition the whole of the spectra of reflectances in 100 homogeneous and compact subsets (Fritzke, B., 1994) and (Badran, F., Thiria, S., Yagoub, M., 2001). Each subset is associated to one cell of the map and is characterized by a prototype spectrum which we call referent. This model carries out the property of the conservation of topology, Two close cells on the map are associated to two close referents in reflectances space. The determination of the referents and the partitions associated with cells is calculated by the algorithm of Kohonen (Anouar, F., Badran, F., Thiria, S., 1997).

The application of this algorithm requires initially the preparation of the training database formed of representative spectra of the studied problem. The algorithm functions in several iterations, with each iteration, we presents successively the spectra of the base of training which make it possible to adapt the referents and the subsets of the associated partition.

The final map is obtained after several iterations. This algorithm is known as "with not supervised training", because no a priori knowledge, on the base of reflectance, is provided to the algorithm. Thus, the quality of the map obtained depends especially on the quality of the base of training and its representative of the varieties of the spectra coming from the studied problem.

At the end of the training, the algorithm of Kohonen associates each cell of the grid a referring spectrum and a function of assignment making it possible to assign any spectrum of reflectance to the cell having the referent nearest within the meaning of the Euclidean distance. The spectrum referent of the cell will be representative of all the spectra of the pixels which are affected for him. By labelling each cell of the map, by a given landscape unit, we obtain a model allowing to recognize the unit of landscape in any pixels of the image.

Indeed, the assignment function attributes the reflectance spectrum (in a given pixel of a map cell) to corresponding referent. This referent will attribute in its turn, the pixel, the unit of landscape which is affected for him. The labelling of the cells of the map could be done by an expert (a physician expert) who will analyze the spectra of reflectances allotted to the cell. This step is facilitated by the possibilities of visualization of the data which this algorithm allows.

For a given cell we can visualize the referent spectrum and the subset spectra of the base of training which are affected for him. In addition, the 100 cells of the map (10*10) gather the whole of the data in 100 subsets which can them also be gathered in relatively homogeneous sets the Figure.2 represents the whole of the referents spectra assigned to each respective cell and their classes. These cells are organized in similar groups.

3.   METHODOLOGY

The followed methodology in this article was applied for the classification of the colour of the ocean in LODYC laboratory (Niang, A., Gross, L, Badran, F, 2003). We adapted it to our problems on images with high resolution.

To apply the Kohonen Self Organising Map algorithm (SOM) to the Spot images covering the area of Nouakchott, we took, the sections of images covering the area of study (600*1240 pixels); this section is shown in Figure 1.

Remember that the objective is to characterize reflectances of the units of landscape, described above, from the 3 dates of the same season on the area. Methodology is defined in the following stages.

3.1 The satellite images

The used images in this work on the area of Nouakchott are spot images made up of three bands of which the wavelengths are:
B1: 0.5 to 0.59 μm corresponding to the green band.
B2: 0.61 to 0.68 μm corresponding to the red band.

B3: 0.79 to 0.89 μm corresponding to the near infra-red band.
The dates of the images are:
11-03-1989_11:44:49
11-12-1995_11:45:42
11-06-1998_11:41:06
We took the same section for the 3 available dates. Each section consists of 300 lines * 600 columns * 3 bands. They are the parts of the images on which we have validated data by the experts and digitized on a SIG. Once the method validated, we apply it to the totality of the zone of study.

3.2   Constituting of the base of training

We chose the reorganization of the matrix of image made up of 600 lines * 300 columns * 3 bands in 5040 lines and 3 columns. The lines correspond to pixels and the columns to the channels. We thus obtain for each pixel its three numerical values in each band of reflectance. From this new matrix, we transformed the numerical values for each channel into reflectance value according to the formula given by the guide of user of Spotimage society. By supposing that surface is lambertian and that the reflection is isotropic:

$$\rho_i = Cn_i * \pi / Gn_i * \cos\vartheta * Es \;.. \qquad (1)$$

Where   i = index of the channel, 1 to 3
         Gn = calibration gain of channel i, value given on the header file of the images.
         θ = solar zenith angle.
         Es = Solar irradiance equivalent to channel i given by the Spot site, depends on the HRV and the generation of Spot.

After the transformation of the images matrices into values of spectral reflectances, we proceeded to the constitution of the base of training which is used as a basis of application for the SOM algorithm. This base is consisted of the three dates, by considering that 3 successive lines can present same information on an image, we chose then to take a line from three of each date of image and then to combine their matrix. Thus, we obtain a base made up of 3 dates of our area of study.

The objective of this stage is to constitute a base where all the cases of figure of reflectances representing of the units of landscape are present. The base of training is thus made up; it is identified as multi dates. Standardization, between -1 value and 1 of the values of reflectances, is applied in order to reduce the variations of the values between the dates within the base of training.

3.3   Application of the SOM algorithm

After the constitution of the multi dates base of training, we applied the SOM algorithm, whose principle is explained previously. We thus, obtained the Kohonen map which constitutes the spectra of calculated reflectances representative of the referents of different cells the base of training (see Figure 2). We observe on the map, that the spectra of referents representing the subsets are localised by complying with the rule of conservation of topology and similarity: the close referents present similar spectra. Thus the referents are organised in the map, from the higher reflectances to the lower. In addition to the conservation of topology, the characteristic of this map is the possibility to visualize the pixels spectra of the same subset and their geographical localisation.
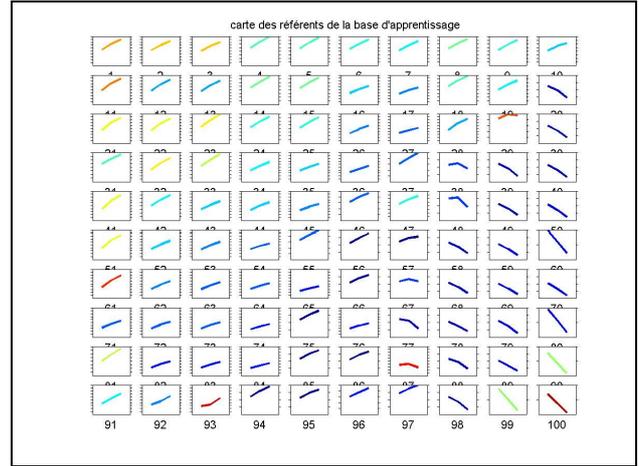

Figure 2. Spectra of the referents classified on the Kohonen map

3.4   The application of the HAC classification

In order to reveal these similar groups, we apply an Ascending hierarchical clustering (HAC) to the Kohonen map. While supposing at the beginning that we have 100 subsets, each one being represented by a cell. Each iteration merges two subsets in only one and thus reduces the number of subset of one unit. In this manner, the number of subset falls during iterations to arrive at only one subset when the algorithm arrives at the end. It is possible to stop this algorithm with a given iteration and to thus recover a definite number of subsets.

The application of the HAC requires the use of a criterion of similarity between the sets. Several criteria are defined in the literature; we chose that of Ward for this application. This stage permits to gather the subsets (cells) having similar reflectances, therefore to gather all local variability of the landscape.
We stopped the HAC to 15 classes. 15 is the optimum estimated number fixed by the experts on the study area.
We note that each class gathers close cells on the Kohonen map (thus similar subclasses). Each class on the map is represented by a colour (Figure.2), it can be also visualised geographically on the original image.

The visualization of the 15 classes gathering the 100 calculated subsets, are labelled to make correspond one or more classes to a landscape unit on the ground. These units present the elements factors of risk. The class of dunes is an example compared to the urban zone.

3.5   The multi dates application

After having identified the classes which correspond to the units of landscape, the following phase consists of the assignment of the results of the base of training classification on each date of image. This phase makes it possible to locate each unit of landscape on each date of images and to visualize the evolution of each class on the three dates available.

The classification is realised without calculation but by simple assignment of the 15 classes on each date. Thus we see the evolution of the two risks on the various dates (stranding and flood) compared to the urban areas of Nouakchott. Figure 3 shows the various stages of the methodology of work.
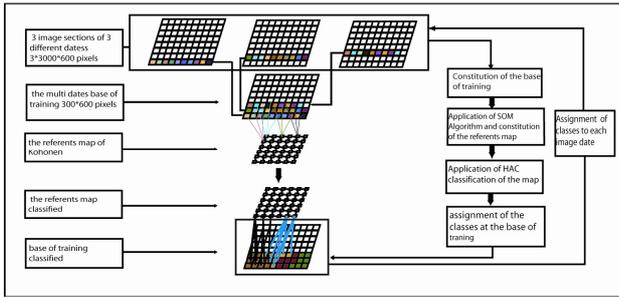
Figure 3. Methodology of the application of SOM algorithm

4. RESULTAT

The classification results was validated, on each date, by a comparison between the calculated spectra of the referents and the theoretical spectra and with those of the ground for each unit of landscape. Validation on the ground is carried by the localization of the class pixels on a georeferenced image compared to ground data taken on this area.

The other method of validation is made by comparison with the digital map obtained by photo-interpretation and from the ground data. This map of validation covers 300*600 pixels. The difficulty of classification lies especially in the separation of the various existing sand classes on the ground. It's question to make separation from the various sand classes of dunes and to separate also from the sand classes and the coastal dunes.
Algorithm SOM presents a clear improvement compared to the k-means algorithm, in particular for the classes having high reflectances (classes of dunes)
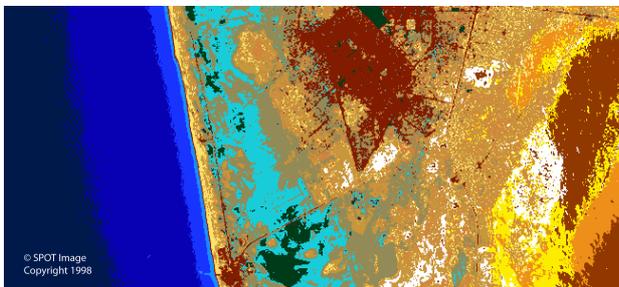

Figure 4. Classification of the validation zone 06/06/98.
Caption is same then that of Figure 5 caption

For the class "dispersed urban zone" the percentage of the classified pixels is lowest whereas the percentage of the false classes is high. That is explained by the use of the dunes sand in like materials of building (the sand is extracted from the dunes). See Table 1.

Algorithme	L'algorithme SOM		k-means
	Error class	classed	classed
zone of breaking of waves	5.8	80.31	74.37
Zone humide de la lagune	9.68	78.12	71.47
Dispersed urban area	28.31	69.74	67.58

Fixed yellow dunes	13.52	78.97	57.43
costal dunes	17.08	74.26	62.15
Deposit of dune	15.32	71.51	58.91
Inter dune	23.68	73.14	63.52
Nouakchotian Surface	6.74	72.43	66.03
Lagoon of the Aftout	13.31	72,34	70.39
Wetlands of the lagoon	9.68	78.12	71.47
zone of water resurgence	11.5	82.71	76.11
Dense Urban area	11.13	71.83	68.72
Vegetation	7.56	81.01	80.34

Table 1. Results of classification by SOM algorithm

The application of this method, on the totality of the study zones on the three dates, made it possible to characterize 71% of the units of landscape of the environment for three dates. Table 2 summarizes the changes of surface states in the three dates, year 89, year 95 and the year 98. We note a strong increase of the urban areas (180%).
For the Eastern part of the city; even if the large "dunes of Ergue" did not change appreciably, there is a movement of sands in the South-western North-eastern direction. It appears by the growth of deposit layer of dunes and thus by the reduction of 55% of "inter dunes" class and in 43% of "nouakchotian area" class.
In the East of the city "the flooded zone" of the lagoon decreased by the transformation of the pixels into "wetland zone of lagoon" and into "zone of turbid water 1" (see Figure 5, wetland zone of lagoon) following the strong hydrous erosion exerted by the sea in the south of the port.

	area %		
Class Name	year 89	year 95	year 98
zone of breaking of waves	2,09	1,74	2,17
Turbid water 1	8,92	6,55	0,90
Turbid water 2	8,04	10,81	6,86
Limpid water	7,63	7,72	17,27
Wetland 1	1,38	0,53	0,67
Wetland 2	1,99	2,36	3,34
Wetland 3	2,13	4,47	5,97
Flooded zone	0,29	0,30	0,24
Urban zone	4,74	7,50	11,19
Costal dunes	1,20	7,88	6,13
Old dunes	3,48	4,59	4,92
Ergue dunes	11,85	7,61	10,39
Inter dunes	4,93	3,30	2,69
Nouakchotian soil	8,34	4,18	3,62
cost area	0,49	0,78	0,43
Deposit of dunes	2,52	3,48	2,46
Vegetation	0,78	1,14	0,54

Table 2. Results of classification on three dates of images

1. Example of image to be classified Spot 11-03-1989

2. Classification of the image Spot 11-03-1989

3. Classification of the image spot 06-11-1998

Wetland 1	Flooded zone	Ergue Zone	Deposit of dune
Wetland 2	Turbid Water 1	Old dune	Vegetation
Wetland 3	Turbid Water 2	Nouakchotian soil	Limpid water

Figure 5: Evolution of the classes factors of risks on the area of Nouakchott

The flooded zones in the lagoon are those due to water resurgences. It is appearing in the medium of the "zone of construction". Figure 5 shows the evolution of each unit of landscape at the three dates. Vegetation surfaces did not grow in this area.

Figure 5. Evolution of the classes on 3 different dates

4.1 Discussions and prospects

The method of self organizing map classification is based on the characterization of the units of landscape from the reflectance values. However, these values vary for the same unit according to the season and other physical parameters, solar radiance and climatic conditions. To arrive at a more exact characterization of the referents representing the units of landscape, it would be necessary to have a larger base of images on the area so that all the cases of reflectances are presented at the referents map. More the base of training is rich; more the map of referents is exact.
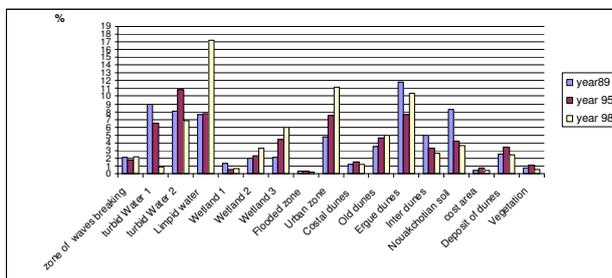
In this case of application, we are limited to 3 images of the same season and a fourth one for the validation. The spectra of the calculated referents are relatively close for the three images. The map of the referents generated is thus valid only for this season, because reflectances of the units of landscapes changes from one season to another.

The physical properties of certain units of landscape, like the fixed dunes and the city, do not change appreciably, therefore their spectra are stable. It was thus easier to characterize them.

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