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Remote sensing and diachronic analysis of the dynamics of vegetation cover in the Middle Atlas (Forest of Ain Kahla)

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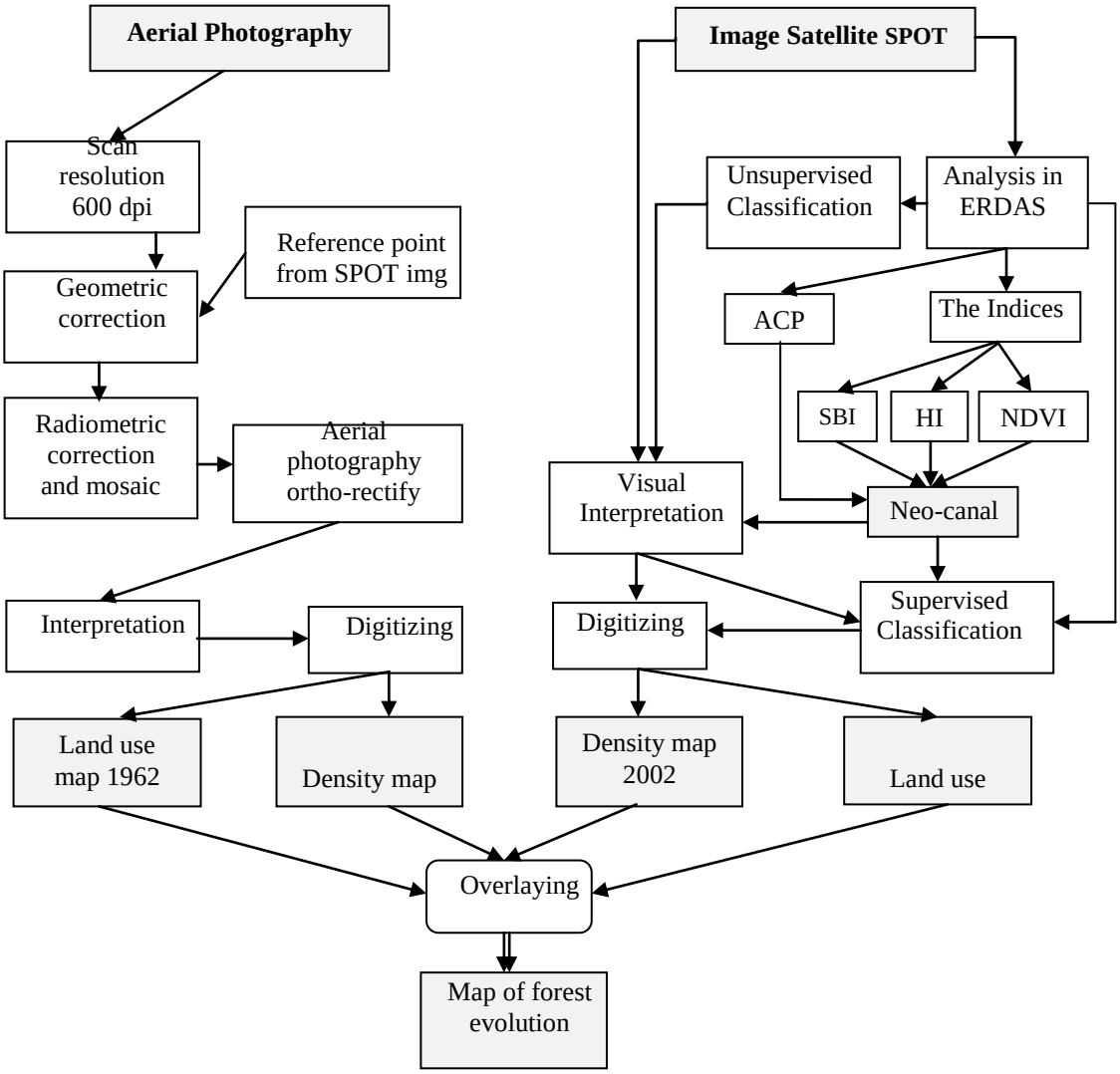
Abstract
Ain-Kahla forest is one of the beautiful Cedar forests in the Middle Atlas, Morocco. In addition it plays a pivotal role revitalizing *Ain-Leuh* economic farming. This forest has been managed by the HCEFLCD since 1941. Today with the application of advanced information and communication technology (GIS, Computer, Satellite images ...) we can monitor the evolution of forest resources and realize a reliable diagnosis on its current state. The diachronic mapping is based on GIS and Remote Sensing, in form of aerial photographs of 1962 (scanned and mosaicked), and a SPOT image of 2002 with a 10m spatial resolution (processed and modeled). We have used the GIS to produce land use and density maps of vegetation cover. The Oak Grove grew by 10.7%, and the Cedars forest has lost 0.3% of its original area (7.2 ha in forty years): A decline that occurred in reality as a result of the decaying cedars. The Juniper devotees saw a deterioration between 1962 and 2002 with a percentage of 4.1% (17.81 ha) because of overgrazing and increasing domestic needs of the local population. From these statistics the oak remains the only tree species that has been growing successfully. Usually the result of forest density in the drill shows that *Ain Kahla* experienced a gradual evolution may be due to sequences of development and settlement, and of forest cuts.
Keywords: Remote Sensing; GIS; Middle Atlas; Forest; Ain Kahla; aerial photographs; satellite; diachronic analysis;

1. Introduction
The Middle Atlas is part of the Atlas Mountain range in central Morocco, lying between a plateau and plain region (Northwest); and the main part of the Atlas Mountains (Southeast). It's a solid mountainous mass of 350 km in length in the North-East of Morocco with a unique charm. Middle Atlas biodiversity, in both fauna and flora, makes it a significant tourist destination. Atlas cedar *(Cedrus atlantica)* forms forests on mountain sides at 1,370 to 2,200 m of altitude, often in pure forests, or mixed with Holm oak (*Quercus ilex).* These forests can provide habitat for the endangered Barbary Macaque, *(Macaca sylvanus),* a primate that had a prehistorically much wider distribution in northern Morocco. Because of its elevation, the Middle Atlas experiences snow during the winter months and a cool climate during the summer.
Ain-Kahla forest is one of the beautiful Cedar forests in the Middle Atlas and the revitalizer of *Ain-Leuh economic farming*. It is also a tourist zone among the beautiful cedars and the RAMSAR site of the Lake *Afennourir* and hosting one of the world's largest population of the Barbary macaque (*Macaca sylvanus).*

2. Methods

The remote sensing in the form of aerial photography has already been accepted as an important utility tool in forestry since the last half century. There are certain fundamental photo/image characteristics which help in the interpretation. They are tone, texture, pattern, size, shape, shadow coupled with site and association. The classification through digital techniques generally takes care of only "tone" without having any consideration for other variables like texture, shape, size, pattern, association and location. Therefore, the similar spectral responses from different objects and dissimilar spectral responses from similar objects cause spectral confusion leading to misinterpretation. However, the image ratios do enhance and suppress the effect of shadow. There are several data processing operations shown in the following chart:



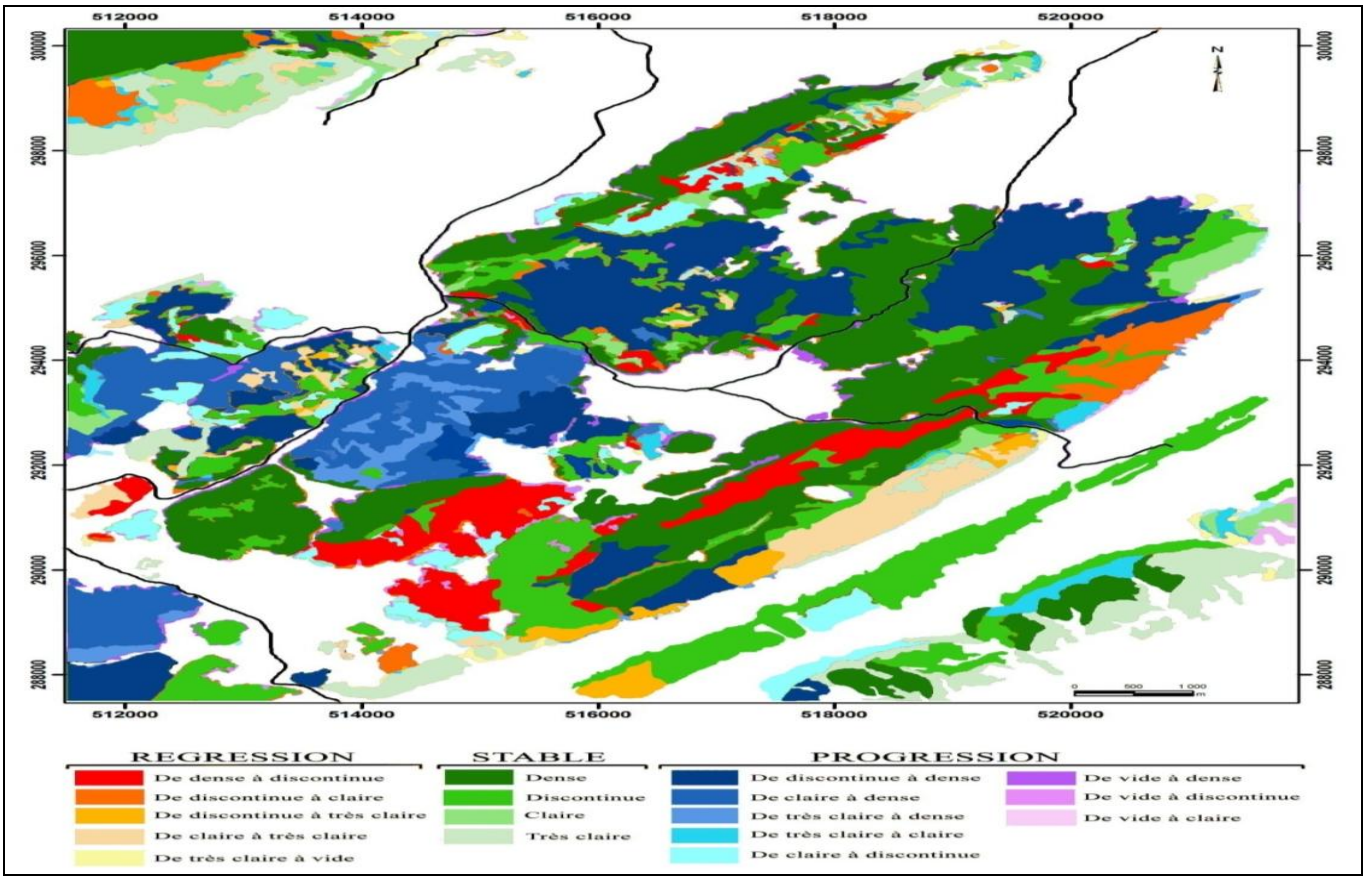
SBI : Soil Brightness Index = $\frac{\sqrt{G^2+R^2+nIR^2}}{3}$; HI : Humidity Index = $\frac{MIR-G}{MIR+G}$

NDVI : Normalized Difference Vegetation Index is one of the most widely used vegetation indices. This is a relatively easy index to compute, and is based on visible red and near-IR reflectance values: $\frac{nIR-R}{nIR+R}$

NDVI values are in the range of -1 to +1 and are an indirect measure of photosynthetic activity of living plants or "greenness." Negative values generally represent clouds, snow, water, dead trees, or other non-vegetated areas. The more the NDVI is high, the more the vegetation is "green".

3. Results and discussion

Generally, the forest has changed between 1962 and 2002 reflecting a density evolution. This development is detailed on the map of density evolution that is the result of the overlay of two density maps (1962 and 2002). Finally we extracted 17 classes; five are regressive classes, four are stable and eight are progressive.



Density Evolution map of Ain-Kahla Forest between 1962 and 2002

The oak has changed by about +10.7% of its area since 1962, from 1824.73 to 2043.60 ha in 2002, with an increase in total area by 218.87 ha. The oak is the only species that experienced a positive development. The cedar has lost -0.3% of its original area, or 7.2 ha in forty years. This regression is manifested on the ground by the decay of cedars scattered or sometimes in groups of adults. The red areas in the map correspond to areas where monkeys live.
The result obtained for the forest density shows that the Ain Kahla forest knows a gradual evolution may be due to the estate planning and settlement of forest cuts after cuts in illegal land. The classification of this forest into four forest classes (cedar, oak, mixed forest, Juniperus thurifera) is based on a diachronic study of the difficulty, because it is difficult to separate the mixed forest of cedar, where the effect shading changed outcomes. Here, objects are identified, not isolated, but in their entirety to give meaning to their cohabitation following deductive reasoning of the photo-identification. Thus, the photo interpretation involves knowledge of all disciplines oriented towards the study of the phenomena. To do this, the operator must verify the results of field audits: the "ground truth".
The study area is dominated by elongated reliefs from Southwest to Northeast, where most of the slopes are exposed to the South-East and North-West. In other words, between the sunny and shady slopes; more than that period is seen taking the morning when the slope shaded (North-West) are more humid than the sunny side (South-East), and we know that the band mid-infrared is very sensitive to moisture values and visible bands will be changed as a result. We found that these areas vary mostly between the cedar forest on the slopes North-West and the oak forest on the slopes South-East. So that's why the field study is desirable, no field study mapping remains incomplete, but only the density can be practical.
The effects of recent drought are mainly water-demanding for species including cedar affected by the phenomenon of decline and whose recovery is difficult at the northern limit of its range of distribution.

4. Conclusion

The diachronic study of the forest evolution by aerial photographs and satellite images are outstandingly suitable working tools for understanding changes in land either dynamic or constantly changes. It reveals more easily the land surface and reproduces with great accuracy the situation on the terrain. In this study, we discussed different methods of mapping applied to a forest by remote sensing and GIS. Emphasis was placed on the satellite imagery, aerial photography and photo-interpretation already well used and developed. The main problem of this study was the lack of resources available for validation. The photo-interpretation method widely used to date on aerial photographs still commits a lot of resources and time, and a very good knowledge of the terrain. Supervised classification has been difficult. The results confirm once again the need for higher resolution images with the disappearance of the forest patches that are getting smaller. It appeared that the results depend in a large part on the person who implements them further the fact that they are not easily reproducible. The vegetation index finally allowed us to separate the different classes of vegetation due to large differences in density.
The study of the environment showed insufficient results. We believe development of remote sensing and the providence of very high resolution imagery will allow us to go further in the detection in remote sensing study of vegetation and land use, including techniques of photo-interpretation and multi-spectral imagery (either alone or coupled with a panchromatic image)

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