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Study of the spatio-temporal dynamics of the Ait Daoud ou Ali (Central High Atlas, Morocco) Forest using geospatial techniques

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For a long time, Man has sought to exploit natural resources for daily purposes (Bouiadjra *et al.*, 2011; Labhar, 1998) to ensure his life and his needs. Thus, the current scientific and technological development has facilitated and given him real opportunities for the overexploitation of natural resources in general and plant cover in particular. For this, the protection of natural resources in general and the forest resource in particular has become today, in the global context of climate change and the emergence of the concept of sustainable development, a major challenge through the proposal of laws (Law 11-03, Law 12-03 and Law 22-07) and also through the creation of protected areas and national parks (Hili & El Khalki, 2017). This came with the aim of creating a certain bio-ecological balance and facing climate change whether at the global or local scale.

Considering the contribution of spatial remote sensing and GIS tools, especially in the crossing of maps, the detection of degradation areas and areas of forest progression, the use of these tools has become very interesting in studies of the spatio-temporal dynamics of vegetation cover (Hili & Abdelaziz, 2021; Gansaonré *et al.*, 2020; Bissour *et al.* 2018; Sbai *et al.* 2018; Bouzekraoui *et al.* 2016; Daoui & Fatemi 2014; Brou 2010; Mahamane *et al.* 2007; Hountondji *et al.* 2004; Nguessan *et al.* 2003; Demaze 2003).

Indeed, the studies that have been conducted on the dynamics of the vegetation cover (Hili & Abdelaziz, 2021; Gansaonré *et al.*, 2020; Bissour *et al.*, 2018; Sbai *et al.*, 2018; El Mazi *et al.*, 2018, Raogo, 2018, Diop *et al.*, 2018, Bouzekraoui *et al.*, 2016, Daoui & Fatemi, 2014, Soro *et al.*, 2014; Tra Bi, 2013; Bouiadjra *et al.*, 2011; Dawson *et al.*, 2011; Brou, 2010; Mahamane *et al.*, 2007; Demarteau *et al.*, 2007; Hammi, 2007; Ouloukou



et al., 2006; Jeffrey et al, 2005; Hountondji et al, 2004; Carmen Salazar Conde et al, 2004; Nguessan, et al, 2003; Demaze, 2003; Dupouey et al, 1999; Labhar, 1998; Thimonier, 1994; Benabid, 1985; Lecompte, 1986; Michel & Ruelan, 1967), have shown that the latter is often influenced by several factors, notably climate, topography (slopes, exposure of slopes and altitudes), lithology, pedology, and of course anthropic actions, whether conscious or unconscious.

For this reason, we propose this multi-chronic study of the Ait Daoud or Ali forest (with an area of 53785 ha), located in the central limestone High Atlas (Kingdom of Morocco). Given that this study area is located in the central High Atlas and characterized by a natural and human context very diverse, whether geographically, topographically, geologically, climatically and anthropically, or also from the point of view of its vegetation cover.

The objective of this work is the application of geospatial processing techniques on geographical data, and the evaluation of the contribution of spatial remote sensing for the quantification of the spatio-temporal dynamics of the vegetation cover of the forest of Ait Daoud or Ali over a period of forty-eight years between 1972, 1999 and 2020. This methodological approach consists in detecting changes (regression or progression) in the vegetation cover, from the calculation of the Normalized Difference Vegetative Index (NDVI), and a supervised classification of satellite images of different dates (1972, 1999 and 2020). Thus, the results obtained in this study and other studies that came afterwards (on the commune of Aghbala (Hili et al., 2021) and on the forest of Ait Bouzid), will allow us to evaluate the effectiveness of the laws and programs carried out for the protection and the safeguard of the Moroccan forest cover in general and the study area in particular.

The multi-chronic classification (1972, 1999 and 2020) conducted in this work has shown that the area of the forest of Ait Daoud or Ali has experienced a very remarkable evolution during the last 48 years. During this period, particularly between 1972 and 1999, we recorded a strong decline in the area of vegetation cover in favor of surfaces devoid of vegetation with 12% in the southeast of the study area. This decrease is involved in a particular climatic context, where Morocco has experienced long periods of drought (the 1980s). After this period, especially between 1999 and 2020, Morocco has committed to propose and adopt several regulations and laws, for the protection of nature in general, and the richness of its biological diversity in particular. Certainly, this policy has borne fruit a few years later (even if it remains very modest at the scale of the Central High Atlas and the region of Beni Mellal-Khénifra in particular). In the area of the forest that is the subject of this study, we can note a progression of the vegetation cover (in general) with 22%. Despite this progression, the study area still records a loss of 10% of its vegetation cover.

The classification results obtained are satisfactory, its validation was verified by direct observations of the spatialization of areas during field trips, and also by comparing the results obtained from the classification of the tool "Region of Interest" used under the tools of spatial remote sensing, with that of the classification "Maximum Likelihood Classification" carried out using Geographic Information Systems. The study of these two methods showed a high accuracy of the overall treatment, with a small difference between the areas that varies between -0.26% and 0.32%.

In general, it must be said that the spatio-temporal evolution of the vegetation cover is influenced and linked essentially to the conjunction of several natural factors (climate, altitudes, exposure of the slopes and the lithology) and anthropic.

This study has highlighted the impact of anthropic actions including the use of wood for timber, for the construction of houses, for heating (socio-economic use of the forest resource) as well as the impact of overgrazing and agricultural activity in the forest area (agroforestry), given that the main activity of the local population is in agriculture and livestock) The use of geospatial techniques has allowed us to have very precise information relating to the spatio-temporal evolution of retreat and also of the progression of the vegetation cover in the forest of Ait Daoud or Ali.

For this, we can consider that the method used in this study, which combines both the analysis, visual interpretation and digital processing, is satisfactory and operational, it can therefore be applied to all studies dedicated to monitoring the dynamics of space-time vegetation cover.

