Felix-Marie Abel and his Vision of Nature in Palestine: *Géographie de la Palestine* revisited

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Felix-Marie Abel was in the early 20th century one of the most prominent "Bible scholars" and, despite limitations, contributed to a better knowledge of Palestinian history and geography. The present paper is an overview of Abel's monumental Géographie de la Palestine focusing on chapters dealing with plants and animals of Palestine. We show that this analysis of historical texts could be useful to make comparative studies with the situation of nature in Palestine today.

Keywords: Palestine, nature, flora, fauna, plants, animals, geography, science

Introduction

Interest in the geography of Palestine before the modern era started with Greek philosophers like Herodotus, who talked of the characteristics of the salt lake (the Dead Sea) found in a "province of Syria" (Nissenbaum 1993) to studies by travelers like Ibn Batuta in 1325 (Baldensperger 1917) to other works in the late Middle Ages (see Avi-Yonah 1962; Hütteroth and Abdulfattah 1977). In the 19th century there was renewed interest in the geography of the area using more scientific principles (Ritter 1866; Hull and Fund 1888; Albright 1921). Further geographic studies where done by Israeli geographers upon creation of that state in 1948 (e.g. Karmon 1971), but these were tinted with a Zionist political agenda (Falah 1989, 1991).As the battle of the new geographies emerged, Zionist versus Palestinian native (Harker 2010), the old geographic literature of the 19th and early 20th century seems to be almost forgotten. This is especially true for non-English manuscripts. We think it is worthwhile to investigate how and why the older geographers came to study Palestine and highlight some of their interesting findings. Here we begin by looking at the work of Felix-Marie Abel (1878-1953), who wrote a two-volume book titled *Géographie de la Palestine* (Abel 1933) but we limit our analysis to areas related to nature.

Who was Felix-Marie Abel?

Father Felix-Marie Abel was a French Catholic archaeologist and geographer born on December, 29, 1878 in Saint-Uze, France (Dussaud and

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Richard 1953). He was ordained February 1, 1897 at Saint-Maximin (Vestition ceremony for the Province of Toulouse). In 1897 he arrived in Jerusalem to study in the École Biblique (Biblical School of Jerusalem) founded by Marie-Joseph Lagrange. He graduated in 1900. He became a member of the Dominican order in 1902. Very soon, Father Lagrange recruited him to become his colleague and to help him get "a clear grasp of physical environment and the cultural framework of the Bible", therefore taking part in the first generation of the collaborators of the School. In 1905 he became a professor of Greek, Geography and History at the École Biblique and served there until his death on March 24, 1953 in Jerusalem. Thus he spent more than two-thirds of his life in Palestine. Beside his activity as a professor, he organized numerous expeditions for the École. He was named by Pius XII as consultant to the Pontifical Biblical Commission in 1940.

He is one of the most famous specialists of Palestine's history, geography and topography. In France he was considered the most notable "Palestinologue" (Palestine expert).He developed modern "Palestinology", including areas like history, geography, linguistics and folklore. His keen critical sense resulted in an incomparable mastery of the history and geography of Palestine that culminated in his *Géographie de la Palestine* (1932), arguably his most well-known work. He was a foremost expert about the area, so it was natural that he also extended his talents to produce tourist guides and also directed the archaeological excavations in Neirab near Aleppo with the École Archéologique Française de Jérusalem.

Together with Louis-Hugues Vincent he had written definitive works on Bethlehem and Jerusalem. The volumes of topographic-archaeological-historical studies on Jerusalem in collaboration with Vincent provided learned advice to governments and scholars for decades (Vincent and Abel 1912, 1922). They also worked together at the excavations of Emmaus, on research on the Cave of the Patriarchs in Hebron, and at the Church of the Nativity. He also published *Histoire de la Palestine depuis la conquête d'Alexandre jusqu'à l'invasion arabe* in 1952, likewise in two volumes, that spans Palestinian history between 70 and 638 A.D. It was his last work. Besides his original works, he also translated important texts such as the *Book of Joshua* for the École Biblique's edition of the bible. His articles in the *Revue Biblique* alone (especially on Greek epigraphy) number over 100. P. Abel's scholarship was as solid as it was extensive. In his personal relations with colleagues of all nations, P. Abel was distinguished by his old-fashioned courtesy and his polished wit.

Géographie de la Palestine

In 1933 Abel published his encyclopedic and monumental *Géographie de la Palestine*, a two-volume study dedicated to Father Lagrange, his

mentor at the Biblical School of Jerusalem. In the first volume, Abel speaks about physical and historical geography and in the second he addresses political geography. Before this work, in 1932 Abel published a *Guide Bleu de la Syrie et de la* Palestine, part of a series of similar books in Europe. This guide was long considered indispensable for anyone visiting the country, but unfortunately not altogether reliable in certain aspects (e. g. desert tracks as many new roads have been built since 1932). In the 1930s there were not many *Guides Bleus* edited about countries outside Europe, but the *Guide* about Palestine and Syria is one of those few. It was written also in a context where Syria was under French Mandate. The Guide Bleu of Palestine and Syria was recommended to any tourist, traveler and likewise to any Orientalist or Biblical scholar interested in the Middle East. Abel took care of the writing of the part about Palestine on his own. whereas the section on Syria is collective. However, the Guide BIeu is actually only a preliminary pathfinder and by no means a complete historical, geographical or archaeological guide to Syria and Palestine. So the *Géographie de la Palestine* can be seen as his more elaborate work on geography of the area. For this study we focus mainly on two chapters of Abel's *Géographie de la Palestine*: Chapter VIII on the flora and the Chapter IX on the fauna. The title of Chapter VIII contains the word "Phytogeography" instead of botany and that of Chapter IX contains the word "Zoogeography" instead of zoology. This is understandable because of the centrality of geography for Abel who also used the term "Biogeography". Biogeography in the modern sense is the study of the distribution of species and ecosystems in geographic space and through geological time. The scientific theory of biogeography grows out of the work of Alexander von Humboldt (1769–1859) and for Palestine this was based on the plants/phytogeography (Zohary 1947; Whyte 1950).

Flora of Palestine

Very often the author speaks about the "syro-palestinian vegetation" because of the proximity of the two territories; Syria and Palestine present numerous similar plants and animals (like the oak *Quercus sessiflora*). Abel points out the fact at the beginning of the chapter that Palestine presents a great variety of species because of its strategic position: because of the proximity of the Mediterranean Sea, the interior desert, and its bridging of Asia and Africa. Abel asserts that 2,136 species of plants had been reported for Palestine, which can be divided into three types: Mediterranean plants, desert vegetation (in the south of Palestine) and tropical vegetation (around the Dead Sea). These correspond to the modern phytogeographical zones: Mediterranean, Saharo-Arabian, and Ethiopian-Sudanese zones. In another section, he speaks of domesticated

plants according to these regions: Coastal region (with orchids, lupines etc), the Hill country (olives, almonds), the Jordan Valley (with many plants similar to Egypt, such as the papyrus and tamarisk).

Abel describes xerophytic (drought-tolerant) plants as generally smaller and shrubby and having elongate and acicular (slender leaf shape, needle-shaped) leaves with waxy cuticle. Sometimes the leaves are replaced by spines. He writes of the Mediterranean evergreen vegetation like *Pinus pinea* or the *Pinus halepensis* and *Quercus ilex*. Abel also speaks about deciduous (tropophilous) trees as being rarer, such as the oak *Quercus lusitania*.

On occasions Abel speaks about ethnobotany, the use of plants for daily life or in the pharmacopoeia. Abel reports that *Balanites aegyptiaca* ("Desert Date" is the common English name) produces "a big olive and its oil is used by the natives against rheumatism" (p. 211). This observation is also confirmed by the *Flora Palaestina* (Zohary 1978): "The oil which constitutes up to 40 % of the fruit is comestible and also widely used in folk medicine and in soap manufacture". Abel also writes that the *Moringa aptera* (Ben tree now called *Moringa peregrina*) produces a seed that has the taste of almond, from which it is possible to make a precious oil used for cooking but also for medicine (against abdominal pain), for cosmetics, and sometimes as a lubricant. The *Calotropis procera* (Sodom's apple) contains a "suc laiteux" (milky sap) of medicinal use. *Solanum sodomeum* is also called *coagulens* because its seeds can curdle the milk ("la propriété que possède sa graine de faire cailler le lait" in the original text, p. 212). He also describes its fruits as having the appearance of small oranges. But although those fruits are beautiful, they are not edible. We can find traces of that belief in *Plant Lore, Legends, and Lyrics* by Folkard (1884, 225): "The *Solanum sodomeum* is a purple Egg-plant of which the fruit is naturally large and handsome. It is, however, subject to the attacks of an insect (a species of Cynips), which punctures the rind, and converts the interior of the fruit into a substance like ashes, while the outside remains fair and beautiful. It is found on the desolate shores of the Dead Sea, on the site of those cities of the plain the dreadful judgment on which is recorded in sacred history. Hence the fruit, called the Apple of Sodom, has acquired a sinister reputation, and is regarded as the symbol of sin."

According to Abel, three areas offer the greatest diversity of plants. Because of its climatic conditions, in the Ghor area includes tropical plants that cannot be found in mountainous and coastal areas (*Mimosa unguis-cacti*, *Acacia farnesiana*, *Ricinus communis*castor-oil tree). Lake Tiberias offers some plants like the thistle *Notobasis syriaca* and a black mustard plant which grows becoming very woody, like a small tree, measuring four meters in height. The edges of the Dead Sea present some

interesting examples of Halophytes (salt-tolerant plants, plants that like a high salinity in the ground) like *Atriplex halimus* (Mediterranean salt-bush), *Salicornia spp.*, and *Suaeda vermiculata*.

Abel devoted an entire part of his chapter to fruit trees. For the scholar, the presence of those fruit trees accentuates the Mediterranean character of the Palestinian landscape. Abel mentions that there is a trilogy of three key fruit trees in Palestine: olive, fig tree and almond trees. He also mentions trees were imported "from Egypt" like the date palm, the sycamore, or the doum palm or from Asia like the white mulberry, Persian walnut, or from Africa like the pomegranate tree. Abel distinguished different types of fruit trees regarding their use and cultivation. Grapes were mostly cultivated in the chalky soil of the Shephelah area, in the clay soil of the plateaus or also in mountains. Less common fruit trees included apple, pear, peach, plum, pistachio, and quince. He also mentions trees cultivated mostly as decorative/ornamental plants such as *Morus nigra* (black mulberry). Abel identified four types of cereals cultivated by Palestinian farmers: barley, common wheat, *Sorghum annuum* and proso millet.

In this chapter Abel mentions different endemic plants such as *Pistacia palaestina* (p. 208) or the Palestinian arum (p. 210). The Latin term "palaestina" in the scientific name indicates its geographical origin. For Palestine we can mention also the Horsetail knotweed (*Polygonum palaestinum*), a plant belonging to the Polygonaceae, whose habitat is principally sand dunes of the coastal plain. Abel does not mention the Pheasant's eye *Adonis palaestina*. But we can forgive this omission as the author says in the introduction to his chapter about botany, that it is a "brief outline" ("large esquisse" in the original French text).

Fauna of Palestine

Abel begins this chapter by writing that most of the animals of Palestine belong to the Palaeartic Region (one of the eight biogeographic realms on the Earth's surface). Abel asserts that 113 different species of mammals have been listed in Palestine, as well as 348 species of birds, 43 species of fish, and 4,700 species of insects. He argues that the greatest biodiversity is in the Jordan Valley and the Dead Sea Region. Concerning fresh water fish, Abel writes that the biggest diversity of species is found in Lake Tiberias. Living there are some spiny-finned fish of the Chromides family such as the Nile Tilapia (*Chromis niloticus*) which has a dorsal fin that is used for defense

Venomous snakes are not common in Palestine and Abel mentions that he knew of no human death by snake bites. The scholar writes about only five species of venomous snakes: the *Daboia xanthina* (Ottoman viper), the *Vipera euphratica* (Levant viper, now *Macrovipera lebetin*)

that is the longest viper in Palestine, the *Echis arenicola* (North-East African Carpet Viper, now *Echis pyramidium*), the *Cerastes hasselquistii* (Horned desert viper now *Cerastes cerastes*; the old name *hasselquistii* refers to Frederik Hasselquist, a Swedish explorer who studied the fauna and flora of Palestine and wrote his observations in a book called *Iter Palaestinum* 1752), and the *Naja haje* (Egyptian Cobra), found mostly in the south of Gaza and Beer-Sheva. Three of these species were already reported by Tristram (1884) who wrote about *Daboia*: "I twice obtained this poisonous serpent, once on the Plain of Acre, and once near Tiberias. On one occasion it had swallowed a full-grown hare whole, and was unable to move. On the other it had just struck a quail, which dropped down dead as I came up with it, with no other mark or injury than a slight scratch close to the tip of its wing". He noted about the *Cerastes hasselquistii*: "I have known my horse rear and shake with terror on descrying this little but deadly Serpent, coiled up in the depression of a camel's footmark, on the path before us". And finally comments on the *Echis arenicola*: "This poisonous little Serpent I have frequently found on the dry sands both north and west of the Dead Sea, but not in the upper country". Abel does not write anything about the *Echis coloratus* (Palestine saw-scaled viper) which is endemic to the Middle East and Egypt.

After the snakes Abel naturally writes about lizards living in *khirbet* (ruins). He also mentions the Desert monitor being captured by workers during the archaeological excavations of Teleilat Gassul on March 10, 1931.

Abel on several occasions speaks about ethnozoology. He notes regarding the wild boar (*Sus scrofa*) that local people hunt it to protect the crops but also to sell its meat to foreigners (p. 221). He mentions that the Arabs eat the flesh of the Indian crested porcupine *Hystrix indica* (p. 222). On several occasions Abel mentions hunting of wild animals including the Nile crocodile from Zarqa River (one killed in 1877, and exhibited in the Museum Saint Anna in Jerusalem, p. 230). Abel speaks eating habits: Jewish and Muslims have a prohibition against eating pork (p. 221) and notes the Jewish prohibition against eating the African sharptooth catfish because it has no scales (p. 231).

Unfortunately some animals are described more by Abel (mammals, fishes and birds) than others (amphibians, bees and scorpions are barely mentioned).Abel uses names of the old classification that are no longer used. For instance, he mentions the *Hyrax syriacus* (p. 221) which is now *Procavia capensis* (rock badger) (Qumsiyeh 1996). Abel refers to the Indian crested porcupine as *Hystrix hirsutirostris* (p. 222), though nowadays the scientific name is *Hystrix indica*. Also for the Desert monitor he uses the scientific name *Psamosaurus scincus*, while today *Varanus griseus* is the scientific term. Some information that Abel gives is obviously

outdated. He mentions, for example, the "renard nilotique" (Nile fox) which is likely *Vulpes vulpes* (p. 223).

Abel's Impressions Regarding Palestinian Nature

On numerous occasions Abel expresses his own viewpoint about the situation of nature in Palestine. He regrets the lack of forest (p. 202) and highlights the semi-dry climate, which gives an impression of the barenness of the land except in the late winter and spring season (p. 205). He emphasized the fact that the plants have an incredible capacity of adaptation to the climate: such as the plants that become thornier in the south of Palestine because of the proximity of the desert. He describes the landscapes at times in poetic terms. For example, he describes the thorny bushes, invading the land in summer with their spines that look like a metallic armor that enters in rivalry during the spring with the patches of flowery plants (p. 210. On page 231, Abel describes the *Tristramella simonis*, a cichlid fish, as being the best to keep the eggs and small juveniles inside its mouth. Abel describes this behavior as a comparison with the pomegranate: "The mouth of the foster father in which are hurrying the alevins like the pips of a pomegranate, is then so distended that the jaws cannot close anymore".

He also points out some problems in land management. He laments the land clearing of the Ghor area ("défrichement") (p. 212). He writes about the disappearance of some aspects of nature/agricultural culture, such as the end of the cultivation of cotton (p. 212), of sugar cane (p. 215, once common near Jericho) and of rice (p. 216).

Concerning animals, at the beginning of Chapter IX Abel expresses shows his astonishment about the diversity of birds in Palestine: "The fauna of birds is extraordinarily rich for an area not that vast". He explains that richness because of its geographical situation: Palestine lies on the pathway of migration between Europe and Africa (an estimated 500 million birds are migrate each year from Europe to Africa through Palestine).

Like plants, Abel mentions animals that have disappeared in Palestine: the *Addax nasomaculatus* (Screw-horn antelope), the *Alcelaphus buselaphus* (Hartebeest), the roe deer, the fallow deer, and the lion, part of fauna that existed in Palestine until the Middle Ages (p. 223).

The reader learns that Palestine offers a great variety of species of bats, that among the gecko population, the "white" one is the most common, that the Anatolian ground squirrel according to him "proliferate like rats" (an invasive species). Among the domesticated animals the broad-tailed variety of sheep is the most common in Palestine. The most common goat is the "*Capra mambrica*."

Abel appears to be a great observer of Nature. He often tells the reader what is striking about one animal. The biological details given

include, for instance, the starred agama that matches its skin to the color of the olive tree (mimicry) and the fact that chameleons are somewhat different in the Ghor area (p. 230). Behavioral details are sometimes given, for instance that the Mango tilapia uses to travel in very big and compact shoals and that is why it is called in Arabic *lubbud*, which means "to stick together". Linguistic details are sometimes given, such as the fact that the Jordan barbel is so named because of its barbs at the corners of the mouth (in French "barbules" in the original text). Feeding details are also mentioned: he notes water snakes eat fish from the river but also from the *Birké* (a large water basin located in the open air used to water the livestock or the plants). Ethnological details include mentioning that the camel is much appreciated for its rich milk but also for its hair, made into fabric.

Palestinian Nature and its Links to the Bible

As a Dominican scholar, on several occasions Abel mentions the Bible when he speaks about a plant or an animal. For instance, in connection with the *Mandragora officinarum*, he mentions the Song of Solomon (7:13), where the mandrakes are praised as yielding a pleasant smell, quoting the Bible: The mandrakes give a smell. In our gates are all fruits: the new and the old, my beloved, I have kept for thee. According to him, the lotus mentioned in the Book of Job (40: 21) is the *Zizyphus lotus,* called in English Jujube: "Under the lotus plants it lies, hidden among the reeds in the marsh". The *Ziziphus lotus* is often regarded as the lotus tree of Greek mythology. It is thought to be a reference in Homer's *Odyssey*, where it is consumed by the Lotus Eaters (or Lotophagi) as a narcotic to induce peaceful apathy. The plant mentioned in Genesis 21:15 could be the *Artemisia herba alba*: "And the water was spent in the bottle, and she cast the child under one of the shrubs".

He writes that often the gorges below sea level have patches of *Nerium oleander* that some people thought was the real biblical rose of Jericho. For him the plant mentioned in the Gospel of Matthew (13:31) in the "Parable of the Mustard Seed" has been wrongly identified with the *Salvadora persica* and could be *Brassica nigra* (p. 212).

Concerning domestic animals, Abel points out that the livestock present in Palestine in the 20th century are almost the same as those described in the Bible. The actual situation of the country is not very different from that in antiquity (p. 221). In page 221 Abel reports that the hyrax (*Procavia*) of Palestine is likely the animal described in *Leviticus* (11:5): "The coney, though it chews the cud, does not have a split hoof; it is unclean for you". He also refers to the Sinai Ibex as the mammal described in the Book ofSamuel (1 Samuel 24:2) "Then Saul took three thousand chosen men out of all Israel, and went to seek David and his

men upon the rocks of the wild goats". He also mentions that the hyena and the jackal are found both in his era and in Biblical times, but recognizes that the wild fauna is less rich in Palestine than previously (p. 224).

Discussion

One year after Abel's work was published, it received a very good review by Dhorme (1934), who praised its depth and breadth of material. We agree that Abel wrote a remarkable work for his era and we regret that this geographical text has received scant attention from scholars to date. Such material is worth a modern reexamination. It is of course possible to critique certain aspects of this work that were due to the background of the author as a Dominican priest, such as his penchant for attempting to locate biblically-relevant stories. Observations in Western early writings on Palestine reveal a ubiquitous phenomenon of Orientalism, both in depictions of the East as a region and attempts to prove the biblical narrative (Jawad 2016; Said 1978). For Abel, as a Catholic scholar, the comprehension of geography (and the components of a territory) is impossible without the enlightenment of passages in the Bible. However, writings on plants and animals certainly suffers less bias than writing about supposed biblical sites. Furthermore, they could potentially give us insight into environmental changes in our area (Qumsiyeh 1996; Qumsiyeh et al. 2014). For example, Abel mentioned an endemic squirrel that he calls the "*Siurus syriacus"*, noting that local Arabs liked to eat its flesh. In fact, Abel wrote *Siurus* instead of *Sciurus*. That misspelling makes the scientific identification more difficult for the reader. *Sciurus syriacus* (*Sciurus anomalus* is the scientific name in use today) is a squirrel that has disappeared from the Galilee but is still found in the forests of Jordan and Lebanon (Qumsiyeh, 1996).

Abel's writing is a testimony of his concern about nature and its evolution and degradation. The scholar seems to be clearly aware of the importance of biodiversity and land conservation as well as the need to have diverse landscapes. In the beginning of Chapter IX concerning the animals, he regrets the lack of forest. He points out the fact that the young sheep and goat livestock is a threat to reforestation: "*L'élevage du petit bétail nuit beaucoup au reboisement dyu pays*". The same finding canm be found in commentary by other authors such as Greene (1898), who wrote of the wild flowers from Palestine: "The hills, now treeless, were once covered with forests, and would be today if only a little care were used in preserving the young growth. But the goats eat the tender leaves, and as a tree reaches a few feet in height, the women of the villages cut it down and dig up its root for fuel".

Abel also remarks on the rarity of the pastureland (p. 220) that therefore does not permit the development of a bovine population. So Abel is

aware that every type of landscape has its utility and can attract new species favorable for the biodiversity of a territory.

He seems also very concerned about the lack of animal diversity compared to the past. He points out and bemoans the impoverishment of the wildlife compared to the antiquity (p. 224). In this ecological connection he is aware of human behavior and the threat it poses to some species threatened by extinction: he mentions that the Druze killed the last Syrian brown bear (*Ursus syriacus*) on Mount Hermon. He points to the dangers of urbanism and human construction and the loss of large cats: "*victime comme d'autres fauves, de la denudation de la contrée, du perfectionnement des armes, de l'accroissement des routes et de la circulation*" ["like other big cats, victims of the denudation of the country, the improvements in guns, the increase in roads and traffic"] (p. 224).

He was concerned about the fragility of some remaining animal populations because of hunting, most especially leopards; in 1911 one was killed between Ramallah and Al-Qubeiba and was exhibited in the museum of St Paul's Hospice in Jerusalem (p. 233). The cheetah is also mentioned by Abel as an endangered species (though probably already gone by that time).

Abel's works cover geography, hydrology, hydrography, geology, climate, and mineralogy. While mostly descriptive, he often gives his own point of view and his theories, making this study more original and personal. He supports for instance the theory of William F. Lynch that the Essenes lived in a complex of small caves near Ein Gedi (which Lynch had visited in 1848) predating the Qumran scroll discovery by decades. The topographical quality of his work was quite influential. According to Murphy-O'Connor (2018) "The ten maps he prepared have served as the prime, but often unacknowledged, source of much subsequent topographical identification".

Abel was also careful to include the name of a plant or animal in the native Arabic. For instance, he notes that the broom shrub (*retem*,) the papyrus (*babir*), and red fruit of the *Zizyphus spina* Christi (Christ's thorn Jujube) is called in Arabic *dom* or *nebeq*. As Dhorme wrote in his review (1934): "*La flore de Palestine qui remplit tout le chapitre VIII sera appreciée même des linguistes. D'excellentes remarques cherchent a fixer le sens exact du vocabulaire botanique de la Bible. De même pour la faune du chapitre IX*." [The flora of Palestine that occupies the entire Chapter VIII would even capture the attention of linguists. Excellent remarks regarding the Biblical botanical vocabulary. Similarly for the fauna of Chapter IX].

We conclude that the study of Abel's book and other older books could be a useful key to understanding Palestine biodiversity and the changes that have occurred in biodiversity over the years due to human

interference as well as referencing old names lost through modernity or through the depopulation of the native inhabitants of Palestine as a result of the creation of the state of Israel. Abel mentions endangered species that faced critical issues beyond his time, for example the Palestinian painted frog (Biton et al. 2013) and *Iris haynei* (Gilboa iris), classified by IUCN as a vulnerable species because of the following reasons as mentioned by the IUCN Red List of Threatened Species website): "Plans for the establishment of a settlement on Mount Gilboa threaten large populations of the species, whilst the security wall built on the Gilboa Ridge has destroyed habitats. Afforestation, grazing and localised collection of flowers also impact the plant and its habitat" (see https://www.iucnredlist.org/species/13161709/18612375#threats).

The writing by keen observers like Abel about an area like Palestine provides an invaluable look into the past to understand the present situation of fauna and flora. Despite the biases inherent in writers and readers looking for "biblical" knowledge as such, significant information as noted above can be gleaned from reading the older literature. We encourage more scholars to revisit such older books especially dealing with nature so as to better understand how the environment has changed in our region.

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Assessment of the Dynamics of Atlas Cedar Decline (*Cedrus atlantica* Manetti) by Remote Sensing in the Aurès area, Algeria

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The aim of this paper is to evaluate the decline of Atlas cedar forest in the Aurès area by studying spatial data, using remote sensing and GIS. In order to show the dynamics of changes during different periods, a multi-data set of satellite images (Landsat: 1987, 1995, 2003 and 2016) have been processed (classification, geometric correction, and segmentation). The Normalized Difference Vegetation Index (NDVI) is adopted with a field request. The data analysis of the dynamic decline of the Atlas cedar allowed us to distinguish three areas (area of increase, of decrease and of no change). The areas of increase showed a great loss of Atlas cedar due to several factors.

Keywords: Cedrus atlantica, forest decline, dieback, change detection, NDVI, Aurès

Introduction

At the national and local level, the forest plays an economic and environmental key role. At present, many forests in the world are suffering from climate change, a problem worrisome for researchers. This climate change could substantially alter the composition, structure, and biogeography of forests in many regions (Linares et al. 2011).It also alters the phenology (Klein et al. 2013; Adams et al. 2015), the morphology (Filewod and Thomas 2014), and genetic variability (Rehfeldt et al. 2014).These changes are starting to emerge in wet and dry regions (Allan et al. 2014).

Forest degradation is a major source of greenhouse gas emissions (Simula 2009).Forests are negatively affected by different factors that spread over a wide temporal and spatial scale, inducing direct or indirect pressure on the state (Requardt et al. 2007).Forests are particularly sensitive and vulnerable to climate change because the long life-span of trees does not allow an adaptation rapid to the environmental changes. Several factors are associated with climate change affecting forest ecosystems which can act independently or simultaneously (Lindner et al. 2010).

Most forests of the world are suffering a decline. The decline is a complex phenomenon whose causal factors can be highly diverse, it is not easily identifiable and it is hierarchical (Mouna 1994). The decline causes a general deterioration which often ends with the death of trees (Landmann 1994). The cedar forest in Aurès is a striking example of this phenomenon.

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The Atlas cedar (*Cedrus atlantica*) is an endemic species of the North African mountains in Morocco and Algeria (Linares et al. 2011); it covers around 300 km² in Algeria. The cedar forest situated in both the Saharien and Tellien Mountains; it represents 1.3% of the total forest area of the country **(**Boudy 1950; Harfouche and Nedjahi 2003**)**. It has a great ecological, floristic, socio-economic and heritage value (Terrab et al. 2006; M'hirit and Benzyane 2006), and the most important Algerian stands are in the Aurès (Benabid 1993). The reason for choosing this species as the subject of study is its rarity in the world and the great controversy about the causes of its death. This long-lived tree is one of the species highly vulnerable to climate change and soil water content **(**Linares et al. 2011).

The decline of cedar is not new. A report by Boudy (1950) indicated that exceptional drought of 1875 to 1888 had already resulted insignificant damage to cedar stands (Bentouati and Bariteau 2006; Kherchouche 2012) and also the 1993-2002 drought (Kherchoucheetal. 2013).

FIGURE 1
Atlas cedar dieback in Aurès, Algeria (Photo: S. D. Belloula)

In the Aurès, the decline of cedar appeared around 1980. In most of the forest, the stands are subject to various degradation factors (irregular precipitation, illegal logging, pasture, trampling, wildfires, etc.). At present, they are undergoing intense degradation that has worsened.

Many hypotheses were proposed about the decline of this species, where a predominant idea was effects of climate change. Since the early 1980s, severe droughts have been related to Atlas cedar decline and mortality (Allen et al. 2010; Beghamiet al. 2012). According to El-tobi et al. (2009); Zine El Abidine and Aadel (2009) and Belloula (2010), a

decrease in water resources following several years of drought and the competition with oaks were probably the main cause of decline. Prolonged episodic and recurrent droughts combined with high temperatures are among the main factors responsible for the physiological weakening of trees and increased vulnerability to other physiological decay processes (Adams et al. 2015; Kherchouche et al. 2013).

Remote sensing offers a means to quantify the frequency and extent of disturbances globally to detect and estimate the land conversion rate (Desclée 2006), to predict forest susceptibility and insect spread (Garrity 2013). This approach is very effective in the extraction of forest change. Change detection, including both bi-temporal or multi-temporal, is one of main applications of remotely sensed data (Campbell and Wynne 2011). Remote sensing has become an important tool for gathering and monitoring land cover dynamics, and numerous algorithms have been developed for detecting land cover changes (Hansen and Loveland 2012).

Landsat imagery is widely used for land cover monitoring and change detection analysis. It allows for improving these types of studies by the use of time-series analysis for comparison of Vegetation Indices (Li et al. 2014), and land cover changes (El-Aziz 2013;Chen et al. 2015).

The Normalized Difference Vegetation Index (NDVI) is one of the most widely used vegetation indexes (Pirotti et al. 2014), employed as indicators for analysing the seasonal evolution of vegetation (Atzberger 2013). The NDVI is an effective indicator for detecting above-ground vegetation conditions (e.g. biomass); this index has been used to monitor the spatial and temporal changes of vegetation cover and biomass production, and assess the impacts of climate changes (e.g., air temperature and precipitation) on land surface phenology at regional or global scale (Zhang et al. 2012 & Mei et al. 2015). It is obtained by calculating the NIR and VIS band of remotely sensed imagery available in time series with medium to coarse spatial resolution (Zhao et al. 2014).

In our current study, we are in the process of sketching a mental illustration, which will allow us to understand the real evolution of forest, especially the dieback of Atlas cedar. Our aim is to exploit the spatial data (multi-data and other data types) to detect the spatial and temporal changes affecting our area of study.

Materials and methods

Study area

The Aurès is located in the northeastern part of Algeria (lat. 35° 10' - 35° 30' N; long. 6° 20' -7° 10' E) **(**Figure1**)**.The Aurès mountain range is characterised by its steep orientation in the southeast and the northwest. The main peaks in these mountains are: Chelia (2328m), Bezez (2141 m),

Aidel (2092 m), Feraoun (2093 m), Chentgouma (2112 m) and Ras Sardoun (1700 m). The area's soil is relatively young and shallow. According to Faurel et al. (1949), the geological substrates are a variety of sandstone, limestone, silica and dolomite with some pockets of marl and shale.

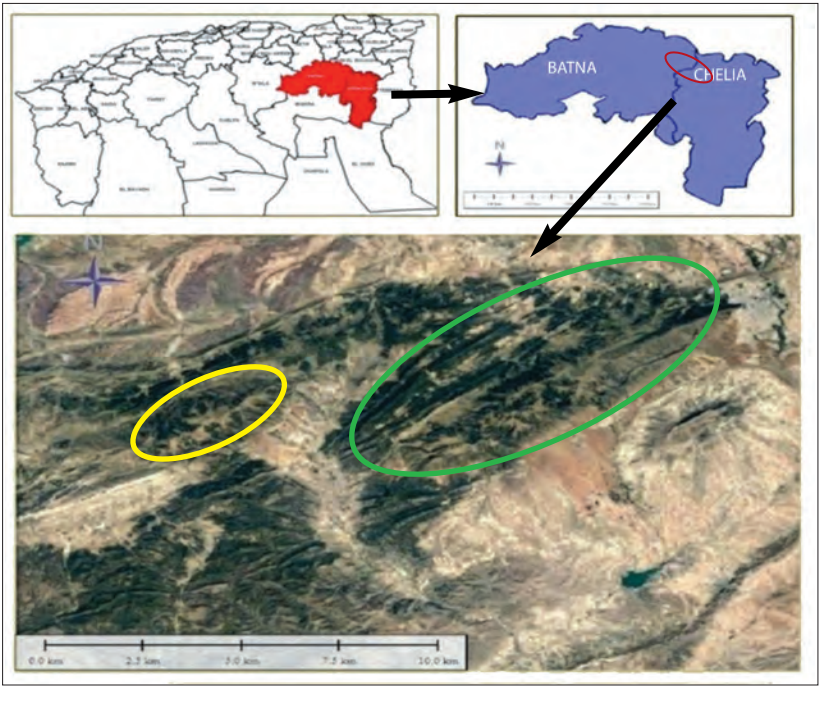
The principal vegetationin the area is comprised of the species *Cedrus atlantica*, *Quercus ilex, Pinus halpensis* and *Fraxinus dimorpha*.

The cedar forest of OuledYagoub (lat. 35° 18' - 35 ° 22' N; long. 6° 37' -7° 05' E) (Figure1) is located at the extremity northeast of Aurès, in its eastern part. It is bound in the north by the Khenchela-Kais road, in the southwest by the valley of Oued Mellagou, and is bypassed in the southeast by the massifs Chentgouma, Ain Guiguel and Ain Mimoun.

Mt. Chélia is located at (lat: 35° 23'-35° 17' N; long: 06°33'- 6° 45'E) (Northeast Aurès Mountains, Algeria) (Figure1), north of the massif of Beni Imloul. It is limited in the north by forest plots and the boundary farm of Oued Tahla, in the south by Oued El Asker and the road linking Bouhmama to Medina, on the west by high lawns and to the east by the Cantina series.

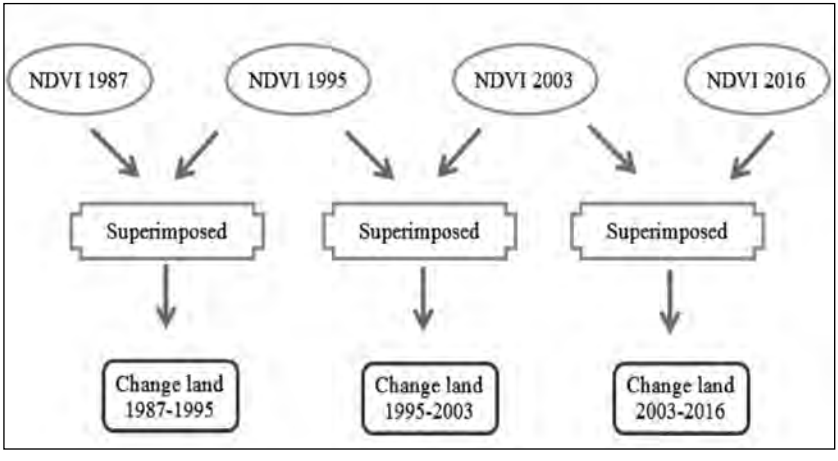
FIGURE 2

Geographical location of the study area "Chélia"and "Ouled Yagoub" Aurès. Algeria. Yellow ellips: Mountain of Chélia; Green ellips: Mountain of Ouled Yagoub



The climate is semi-arid. Average annual rainfall varies from 300 mm in low altitude stations to 800 mm in the highest stations (Seltzer 1946; Schoenberger 1972; Beghami el al. 2013). The average temperature is 15.8 °C. Min. and max. average temperatures are 9.7 °C and 21.9 °C. Elevation of average temperatures combined with rain regressions are estimated at about 368.5 mm, which could have negative implications for vegetative growth.

FIGURE 3
Method of working



Data Collection and Methodology

The study area includes two regions: Chélia Mtns. and OuledYagoub Mtns. The data utilised comprise four satellite imageries (Landsat: 1987, 1995, 2003 and 2016). These images were downloaded from the site United States Geological Survey (USGS) corresponding to the dry season and cloudless conditions.

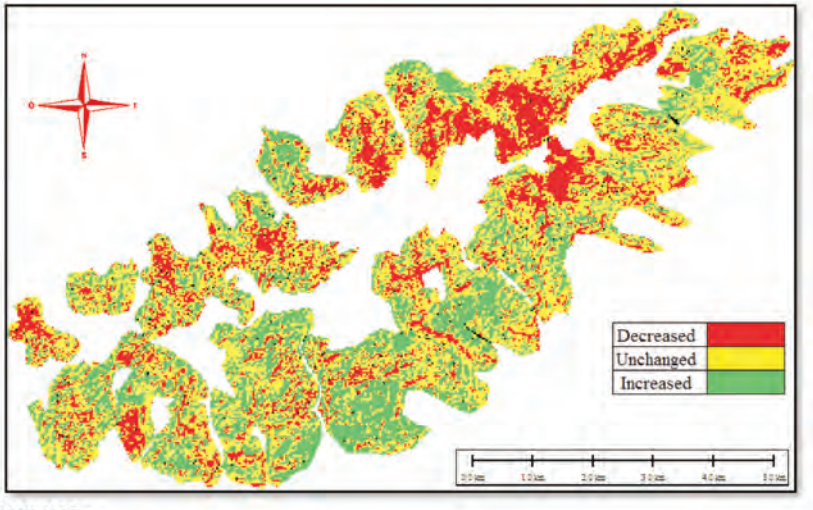
Each image was processed: classification, geometric correction, and segmentation. Identified is a subset located at the stand of Atlas cedar in both areas (Chélia and Ouled Yagoub Mtns.), based on two sources: the geo-referenced phyto-ecological surveys (GPS) and the vegetation map.

The NDVI obtained for every image is a mechanical process (the choice of band 2 and 3 is also selected by the operator). For each image we then created the following: NDVI (1987), NDVI (1995), NDVI (2003) and NDVI (2016).

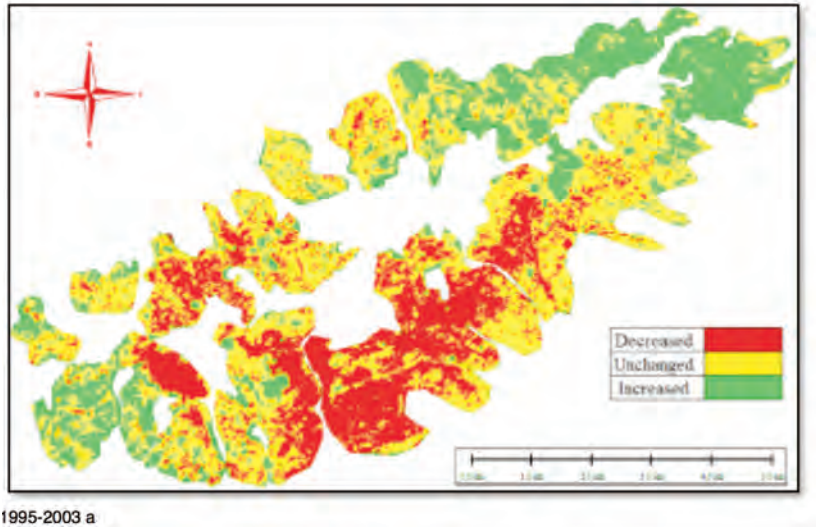
After that we applied the NDVI to the areas of interest in all images; we superimposed these maps (of NDVI) to obtain the differences in the area (NDVI 1987 with NDVI 1995), (NDVI 1995 with NDVI 2003) and (NDVI 2003 with NDVI 2016) (Figure3).

FIGURE 4
Maps of change detection in forest of Cedar (Aurès, Algeria).
For three periods (1987-1995); (1995-2003); (2003-2016)

a: mountain of Chélia; b: mountain of Ouled Yagoub
Green color: Increased radiometry, more active vegetation; Red color: Decreased radiometry, deterioration in vegetation activity; Yellow color: Unchanged areas, stable vegetation.



1987-1995 a

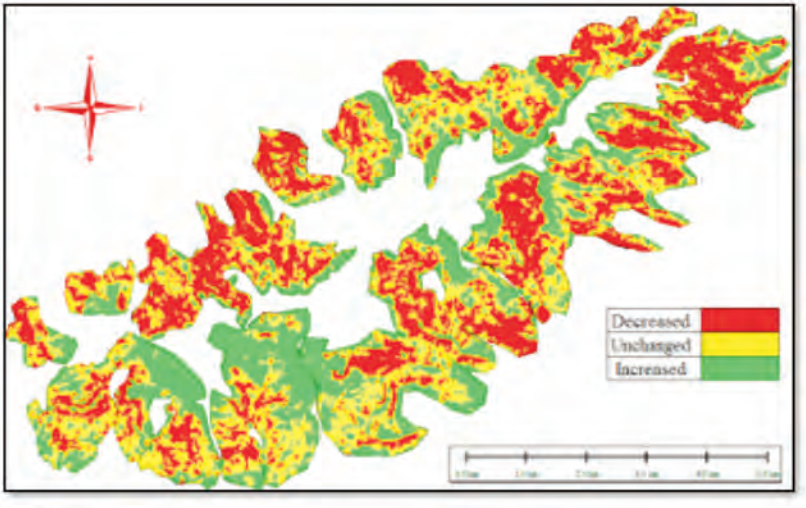


1995-2003 a

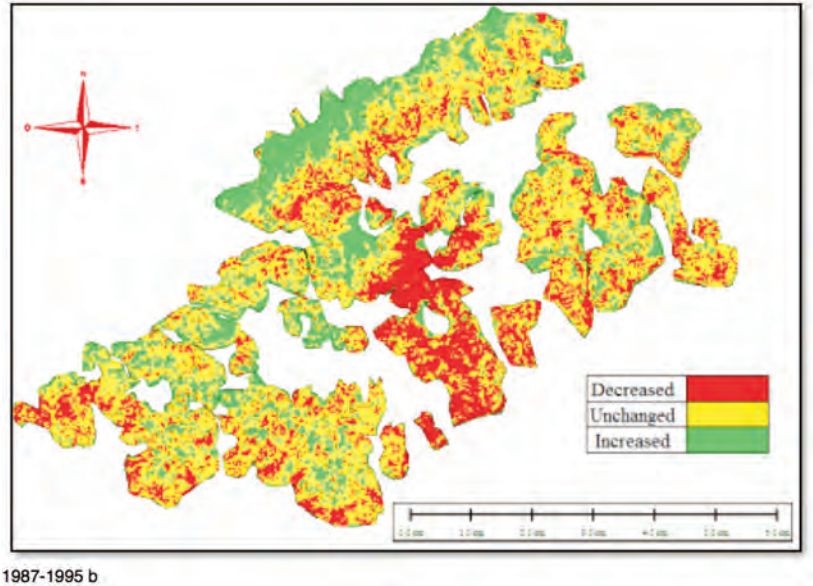
These images evaluate the change in land use and assess where there is an increase, decrease or no change in the area (Figure4).

In our work, we identified different plots (healthy / decayed), and each plot has GPS coordinates.

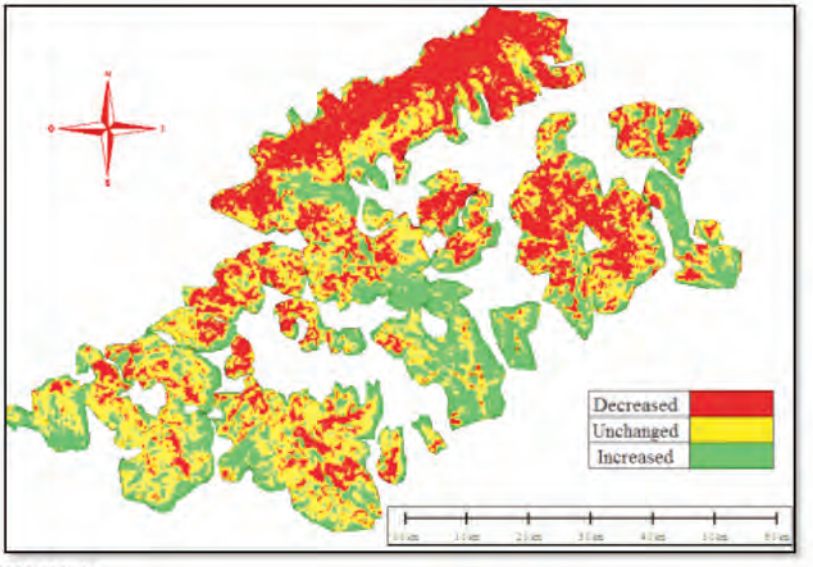
Results



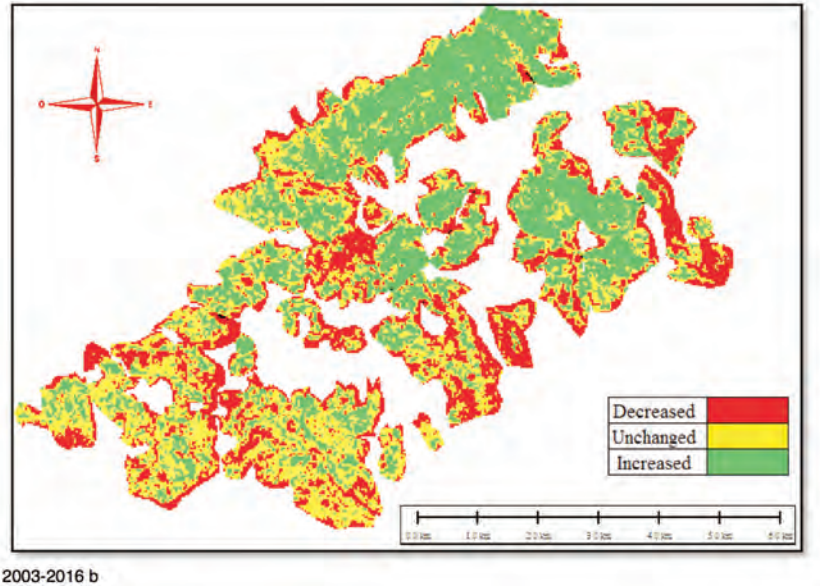
2003-2016 a



1987-1995 b



1995-2003 b



2003-2016 b

Discussion and conclusion

The change detection in the map (Figure4) provides information regarding the distribution, the surface and the change in land use of stands of Atlas cedar. Green corresponds to an increase of Atlas cedar forest, red marks the decrease in Atlas cedar, and yellow indicates no

change in the stand. Generally, the decrease of Atlas cedar is evident on all sides with a higher intensity in the south. This decrease/increase in Atlas cedar is represented by an irregular distribution, as can be seen in Figure 4.

The change detection maps of the Chélia Mtns. (Figure4a) show an irregular distribution between increase/decrease of the stand of Atlas cedar. In the first period (1987-1995), we observed a decrease in Atlas cedar (red) at the level on all sides with a rate of (22.74%). We observed numerous red areas on the north side; that can be explained by the illegal harvesting near the forest. According to testimony by inhabitants of the region, during this period the local population suffered from an excessively high unemployment rate. This led to disastrous illegal felling of trees. Indeed, during these years, Algeria was beset by a very severe economic crisis, marked by the cessation of the import of wood. By contrast, in the second period (1995-2003) the red spotting rate (25.48%) is much more localised in the south, and in another time period an irregular distribution can be observed affecting all sides, with a strong intensity for the period (2003-2016), with a rate of 33.76%. The same picture of change is evident for the OuledYagoub Mtns. (Figure 4b).

The dieback of the Atlas cedar forest in Chélia Mtns. shows an increase from one period to the next, reaching its maximum in the third period (2003-2016). The degradation of the Atlas cedar forest in the Ouled Yagoub Mtns.indicates that this was reduced in the second period by 3.26% and reached its maximum of degradation in the third period with a rate of 32.84%, with an estimated rate of increase of 8.32%.

For both periods (1995-2003) and (2003-2016), the degradation was always at a high level, with the cedar dieback increase at a rate of 1.74%, 7.62%, 4.36%, and 7.39% respectively, for the Chélia and Ouled Yagoub Mtns. By contrast, for the period (1987-1995) the increase in cedar dieback is observed with a higher degradation level, at the rates 6.88% and 9.02% for the Chélia and Ouled Yagoub Mtns. respectively. This is illustrated in Fig. 5. Benmessaoud and Kalla (2008) note that the dense forest decreased between 1987 and 2001.

The large percentage of decrease of Atlas cedar is observed in the period 1999-2007 for the Chélia Mtns. and in 2007-2016 for the Ouled Yagoub Mtns. with a rate of 43.31% and 42.09% respectively. This change is a consequence of climate change.

A check of the change in the land (2016) with the field requests was made. Most of the plots are identical with decreased and increased surface, except for a few plots (about 5%). This is explained by the cutting down of dead trees in these plots, as well as the development of other

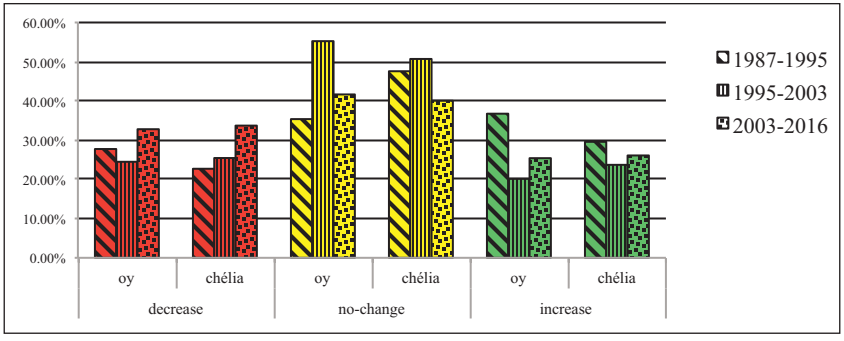


FIGURE 5
Histogram Estimated–surfaces of Cedar in Chélia and Ouled Yagoub mount (Aurès, Algeria).
For three periods: (1987-1995), (1995-2003) and (2003-2016)
Green color: Increased surface; Red color: Decreased surface;
Yellow color: Unchanged areas.

species, especially green oak, which is supplanting the Atlas cedar.Most of these plots where cedar is in a decayed state are at the southern exposure level and they are characterised by a steep slope and different altitudes (low and high).

It is important to note that in each period where we have a decrease, we also have an increase of cedar in both regions; this is explained by the regeneration of Atlas cedar rather than green oak supplanting cedar (Belloula 2010).It is noteworthy that the dieback does not only affect the Atlas cedar forest at low altitude but also at high altitude.

Our findings provide an evaluation during each period when the rate of dieback of the Atlas cedar increases in time and space. The most affected areas are in southern exposure (Belloula 2010; Beghami et al. 2012; cf. Beghami and Belloula (in prep.).

In general, we can say that the use of remote sensing facilitates our approach to detect the change in development and/or decrease in the forest stands and their surface. These findings with the combination of other ecological factors allow us to better understand this change in land use and serve as a basis for the monitoring and management of the cedar. This study shows how remote sensing imagery with a field request can be easier and provides rapid information on detecting change in land cover, over time and over relatively large areas.

Our findings describe for the first time data on the increase/decrease of Atlas cedar forest in time and space, in the Chelia and Ouled Yagoub Mtns. (Aurès, Algeria). These findings will be followed up in future and linked to other ecological factors.

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