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Study of Drought Effects on Three Medicinal and Aromatic Plants Using Field Spectroscopy

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ABSTRACT

Water deficit is one of the major environmental issues affecting biodiversity. Drought-related works are conducted to explore the mechanisms involved in drought vulnerability or resistance and to adopt the most advantageous tool to monitor these changes. Field spectroscopy, an accessory tool of remote sensing, evaluates the reflectance to collect continuous spectrum from materials. In the conducted study, the potential of using UV-Near infrared (NIR) spectroscopy as a non-destructive and reliable approach in monitoring of drought effects on three Medicinal and Aromatic Plants species (MAPs): *Lavandula stoechas, Cistus laurifolius* and *Pistacia lentiscus* from Northern Morocco during dry (July 2021) and wet (March 2022) period was addressed. It was found that *Lavandula stoechas* species is more impacted by water deficit than *Cistus laurifolius* and *Pistacia lentiscus*. Indeed, this species has a lower reflectance in Visible and NIR regions of the spectrum after a period of drought and therefore a higher vulnerability to water deficit than the other two species.

Keywords: field spectroscopy, medicinal and aromatic plants, drought, resistance.

INTRODUCTION

Climate change is a major policy challenge for policymakers and environmental managers. The impacts on the environment are multiple, important and increasingly frequent: droughts, melting glaciers, rising sea levels, tropical storms, etc. The study of its incidence on forest ecosystems is necessary for any initiative aimed at their conservation.

Many years before there were conventional seasons: autumn, winter, spring and summer, but nowadays it can be noticed that global warming affects this distribution. It would be more effective and useful to consider months instead of seasons for climate change monitoring studies. Actually, climate change will increase the disparity in precipitation between wet and dry areas and between wet and dry seasons (IPCC, 2013). Climate change and urban extension have transformed net primary productivity of the Earth (Yan et al., 2021); thus, modifications in vegetation, water availability and global warming are associated.

Hanson and Weltzin (2000) have reported that the seasonal and interannual droughts regularly experienced by plants are expected to intensify in Mediterranean climates due to global warming. The impact of drought can occur in plants across a batch of physiological responses and time scales (Miller et al., 2022). The biophysical reactions of plants to drought are variable over time, and different types of reactions indicators are essential to assess the timing of drought effects (Miller et al., 2022). Drought effects can be seen in vegetation which experienced different drought duration and in different seasons (Zhang et al., 2021).

Hyperspectral remote sensing has the advantage of providing a considerable amount of information about the target being studied, indeed, it furnishes a wide range of contiguous bands which provide accurate identification of chemical and physical surface properties (Goetz et al., 1985); in addition, it has the ability to detect subtle changes in leaf constituents and vegetation structure, making it an invaluable tool for studying how drought stress is expressed and expanded over time (Dao et al., 2021). Ustin et al. (2004) have worked on the use of imaging spectroscopy to evaluate diverse ecological variables and they concluded that it is the only advantageous and precise technique for measuring many important environmental characteristics over wide areas. Field spectroscopy can be considered as an extra tool of remote sensing for the reason that it allows measuring the reflectance from origin and provides field spectral signatures (Rajakumari et al., 2022). Drought stress causes changes in the biochemical, structural and biophysical characteristics of the plant, and each of these characteristics interacts with electromagnetic radiation only in particular spectral region (Peñuelas et al., 1997). Special spectrum bands can be considered for monitoring vegetation stress caused by drought; thus, Liu's team (2022) have stated that the near-infrared reflectance of plants, which is correlated with the number of near-infrared photons reflected by vegetation, is a novel concept for vegetation stress investigation (Liu et al., 2022).

Zhang's team have used a new combined drought index: Palmer modified drought (PMDI) in the area between humid and arid regions in China, they have found that PMDI can be used as an effective tool to attest vegetation change due to meteorological drought. For a better development of terrestrial disturbance, monitoring an ecological aspect of remote sensing becomes essential.

North Africa is located in one of the hotspots of global warming, making it one of the most drought-prone and thus water-stressed regions in the world (Bzioui 2005). In the Mediterranean areas, water deficit has destructive impacts on plant physiology (Dadach et al., 2021); furthermore, aridity causes reduction in soil water potential that retards plant emergence (Krichen et al., 2014). The present climate tends towards drier status in the northwestern region of Morocco with a diminution in mean annual precipitation caused by negative trends in winter and spring seasons (Driouech et al., 2021). In the past, the country had four seasons: mild and wet autumn, rainy and cold winter, mild and dry spring, hot and dry summer. Thus, the climate should be studied on monthly basis and no longer by seasons. Northern Morocco is one of the most watered areas in the country, with an average annual rainfall of between 600 and 1800 mm (HCP, 2020); it is characterized by a humid and sub-humid climate (Born et al., 2008). The average temperature increase simulated for 2050 by all the models is about +1.5 °C compared to 1986–2005 (Woillez, 2019). However, as in other regions, the region experiences irregularities in rainfall from year to year, with occasional periods of drought. Morocco's environmental problems are essentially marked by the almost endemic phenomenon of drought trends under climate change and the depletion of vegetation cover.

There are 4200 flora species grow in Morocco, among them, 500 are potentially medicinal (Sijilmassi, 2016). A science-based strategy is essential to ensure sustainable markets around these plants and to meet the future challenges imposed on MAPs by global climate change. Most studies on drought-induced vegetation stress have focused on forests, but shrublands are also impacted. Understanding the vulnerability of different plant varieties is essential to protect the most threatened ecosystems. For this reason, the use of UV-NIR spectroscopy was considered for the study of the impact of drought episode on shrubland with application on three MAP species: *Lavandula stoechas, Cistus laurifolius* and *Pistacia lentiscus*.

MATERIAL AND METHODS

Considering that climate change affects the distribution of conventional seasons, dry and wet seasons were studied instead. The research was conducted in the month of July 2021 and then during March 2022. For monitoring and assessing the drought effects on MAPs, field spectral data collection was used.

Field data collection campaign

There are many factors which impact plant spectral signature, such as: soil chemical properties, soil reflectance, water availability, time of day, time of year, cloud cover, temperature, etc. For this reason, in both fieldtrips, the same plant samples, the same area with the same soil type were considered in order to reduce the number of influencing surroundings factors. Weather conditions and data collection circumstances for both campaigns were taken into consideration (Table 1 and 2).

The radius of the sampled area is calculated by following equation:

$$R = D \cdot \tan(\alpha/2) \quad (1)$$

where: R – radius of sample coverage area;
D – distance to the sensor;
α – instrument's field of view (25 in this study).

Table 1. Two campaign weather conditions

Date	Wind speed	Temperature	Wind direction	Cloud cover	Nadir measurement	Solar zenith angle
3th of July 2021	9 km/h	23°C	South-South-West	25	11:00 AM	34.00°
1st of March 2022	14 km/h	11°C	East	30	11:00 AM	55.82°

Table 2. Data collection conditions

Condition	Characteristic
Sun exposure	Full sun
Plant foliage density	Dense
Distance to the sensor	25 cm
Radius of sample coverage area	5.52 cm

Field spectroscopy

Field measurements were obtained with these characteristics:

- UV-NIR spectroscopy (range of 300–1100 nm);
- ASD Fieldspec HandHeld spectrometer (Analytical Spectral Devices, Inc., Boulder, CO), with a Very Near Infrared resolution of about 3 nm to about 700 nm with a half width (FWHM: of a single emission line);
- a white reference standard with approximately 100% reflectance was used for calibration and prior to the measurement of each sample, in order to have the same illumination geometry for both the unknown and the white reference spectra;
- all data were collected and treated by the FieldSpec® Dual collection Software;
- the FOV (Field-Of-View) of the instrument is 25° (α).

Meteorological data and MAPs species

The monthly mean temperature and monthly total precipitation (Fig. 1) for the period January 2021–March 2022 were obtained from General Directorate of Meteorology of Morocco (https://www.marocmeteo.ma/).

Figure 2 shows the MAPs species studied in this paper in the field, their characteristics are detailed in Table 3.

Study area

Ain Lahsan is a rural Moroccan commune in the province of Tetouan, in the Tangier-Tetouan region (Fig. 3, Table 4). It is characterized by a subhumid climate with hot summers; consequently, the subhumid bioclimate is ranked first in Morocco in term of MAPs, hosting over 4000 MAP species and subspecies (Jamaleddine et al., 2019).

RESULTS AND DISCUSSION

The precipitation and temperature data for the period January 2021 – February 2022 are in line with the climate projections of the model proposed by Kassogué et al. in 2016 for Northern

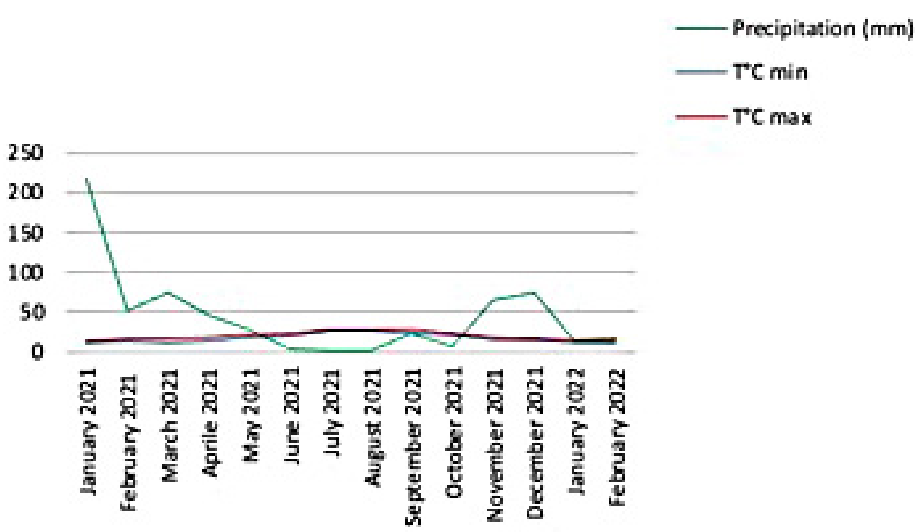

Figure 1. Minimal and maximal temperature and precipitation mean within the period January 2021 – March 2022

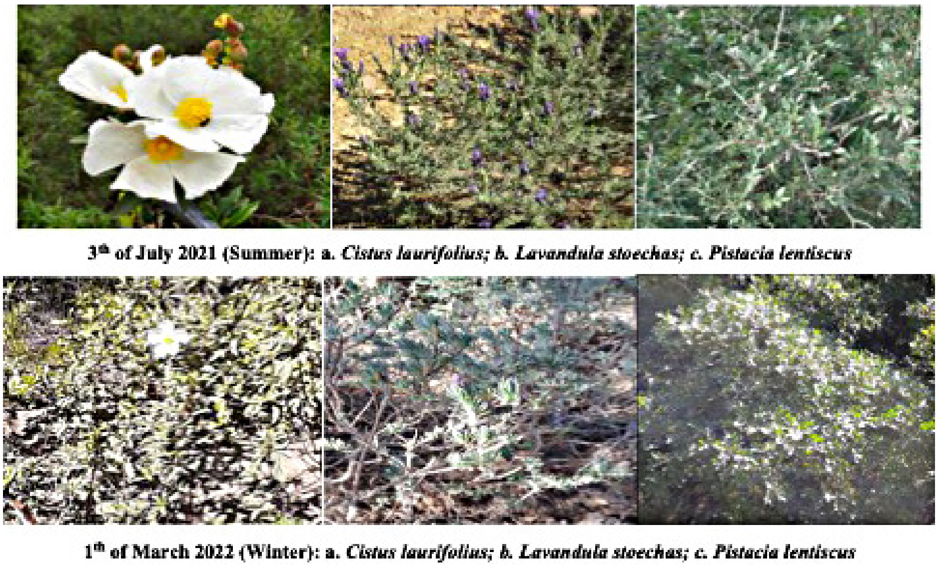

Figure 2. MAPs species in the field

Table 3. MAPs species description in the field– *Cistus laurifolius, Lavandula stoechas* and *Pistacia lentiscus*

Scientific name	Vernacular name	Name in Moroccan dialect	Family	Foliage	Field remarks	GPS coordinates	Growth status	
							3th of July 2021	1st of March 2022
Cistus laurifolius	Laurel-leaf cistus	Chtappa	Cistaceae	Persistent	Grows on dry soil and steep slopes (30-40°)	Latitude 35 ;32 ;52.55 Longitude 5 ;33 ;31.87 Altitude 286	Green plant	Semi-dry plant
Lavandula stoechas	French lavender	Halhal	Lamiaceae	Persistent	Grows on dry, stony soil	Latitude 35 ;32 ;52.56 Longitude 5 ;33 ;31.83 Altitude 286	Semi-dry plant	Dry plant
Pistacia lentiscus	Lentisk pistachio	Drou	Anacardiaceae	Persistent	Grows on moderate slopes	Latitude 35 ;32 ;48.77 Longitude 5 ;33 ;30.27 Altitude 270	Green plant	Green plant

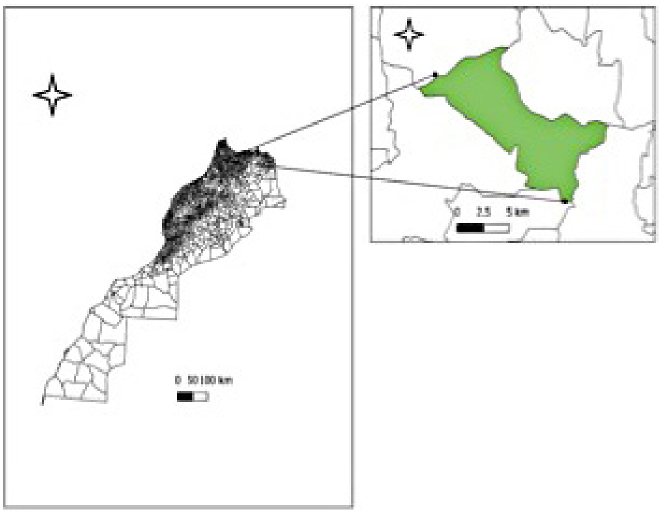

Figure 3. Ain Lahsan Site

Table 4. Coordinates - Ain Lahsan Area

Site	Coordinates	Altitude
Ain Lahsan	-5.55974, 35.54756	230 m

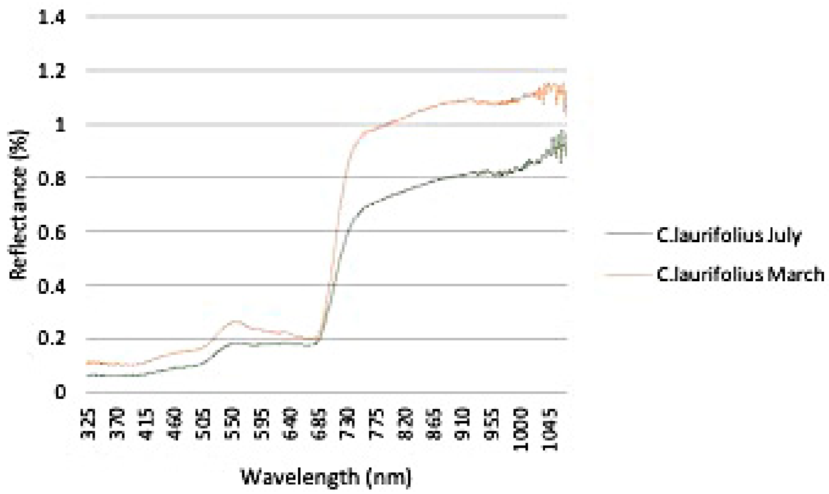

Figure 4. Spectral signature of two campaigns: *Cistus laurifolius*

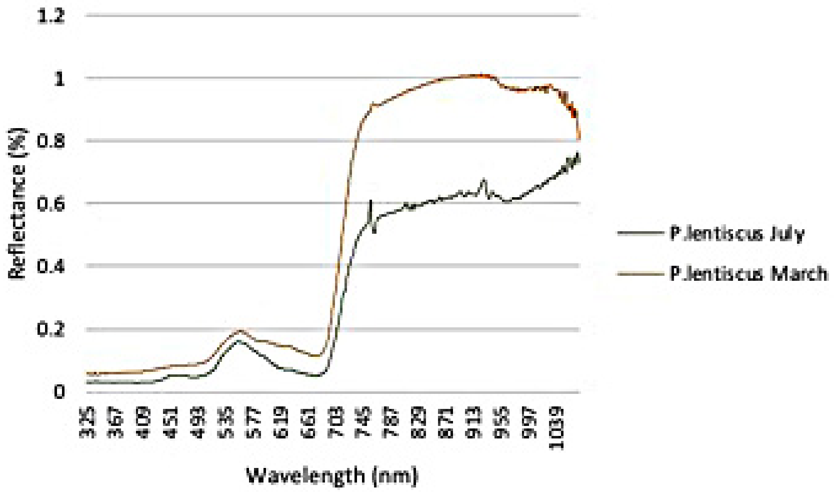

Figure 5. Spectral signature of two campaigns: *Pistacia lentiscus*

Morocco and correspond more to his pessimistic scenario. According to Chakravarty and Kumar (2019), the water cycle depends on several processes, the most important of which are: precipitation, evaporation/evapotranspiration and runoff. The presence of vegetation, albedo and temperature will influence one of these processes over the others. The considered study area is situated in Ain Lahsan woods which is an old-growth forest, Jones et al. (2022) mentioned that this type of forest has large evapotranspiration rate and regular water resources, provided by reasonable peak flows and constant low flows. In fact, plant's resistance to drought depends on the surrounding factors and the plant itself. Knowing that the three species considered grow in the same site with the same climatic, lithological, ecological conditions, etc., the differences in drought resistance shown in this study would probably be due to the reactions of the plants themselves to the environmental conditions. Figures 4, 5 and 6 shows reflectance differences between the three MAPs species as well as the two campaigns.

Spectral variation of leaf pigments due to drought can be observed in 400–700 range (Dao et al. 2021) while 700–1300 range is attributed to mesophyll cell structure impacted by water deficit (Satterwhite and Henley, 1990).

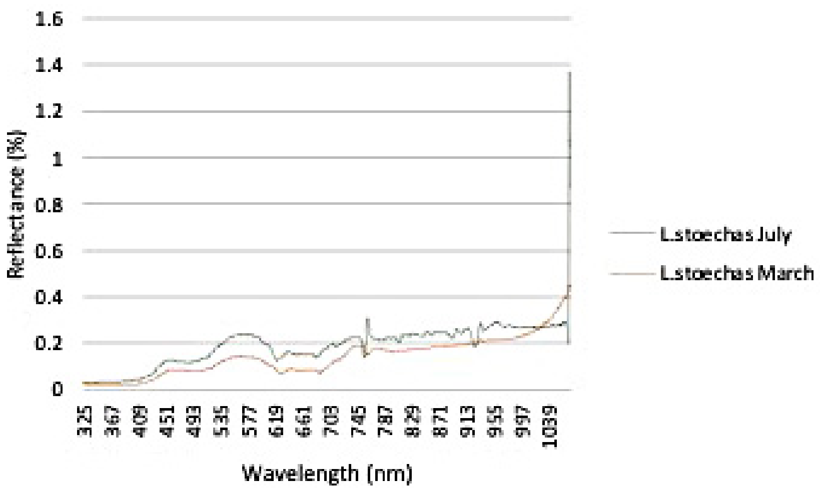

Figure 6. Spectral signature of two campaigns: *Lavandula stoechas*

Figures 4 and 5 exhibit differences in reflectance between two campaigns (July 2021 and March 2022) for *C.laurifolius* and *P.lentiscus*. For both species, it can be noticed that reflectance in March is higher than July in all considered regions of the spectrum. In the visible range, in March 2022, this can be explained by a higher concentration of pigments which results in a green and healthy state of the plant. In very-NIR range, water content influencing the leaf structure may be the cause of the increase in reflectance; indeed, the effect of leaf water on spectral properties includes a direct influence caused by the absorption of water itself, and an indirect influence associated with other leaf properties that are affected by hydration level and water stress (Ollinger, 2011).

In Figure 6, for *L.stoechas*, it can be seen that reflectance in July is higher than in March. The NIR spectral reflectance increases due to the impact of potential water content inside the leaf structure (Liu et al., 2004). Considering the total of precipitation received six months before July 2021 and March 2022 (423 mm-195mm, respectively), it can be deduced that *L.stoechas* leaf structure was impacted by the lack of water content in its growing period; this is in line with the study by Nogués and Alegre (2002) which concluded that the effects on *L.stoechas* were only observed in relative leaf water content and water potential. Dadach's team reported that *L.stoechas* germination rate and water deficit are inversely proportional, which give it limited tolerance to water stress (Dadach et al., 2021).

Comparing the three species, it was found that *L.stoechas* is the most vulnerable to drought stress. Both *C.laurifolius* and *Pistacia lentiscus* have shown a better adaptation to the lack of water availability. This agrees with work of Álvarez et al. (2018) which concluded that *P. lentiscus* is resistant to drought as a result of particular mechanisms such as reducing leaf area, boosting cell wall elasticity and changing leaf gas exchange.

CONCLUSIONS

In the conducted study, it was demonstrated that field UV-NIR spectroscopy can be used as a non-destructive and time-saving novel tool for monitoring drought effects on plant species.

As a result of the drought resistance mechanisms studied and confirmed by other works, *P.lentiscus* and *C.laurifolius* were able to preserve their leaf structures and consequently conserve their optical properties; their reflectance in wet season was higher than in dry season. On the other hand, it was found that *L.stoechas* has a lower reflectance after a period of drought in both Visible and NIR regions of the spectrum; the latter has been correlated to the potential water content in previous studies. Therefore, this MAP species has a higher vulnerability to water deficit than the other two species.

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