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Assessment of the Impact of Covid-19 Related Containment on the Normalized Vegetation Index – A Remote Sensing Study of the Korifla Sub Watershed, Morocco

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ABSTRACT

This study analyzes the impact of containment due to the COVID-19 pandemic on the vegetation cover of the Korifla sub-watershed, based on remote sensing data and spatial analysis. The aim of this study was to analyze the impact of the containment imposed in response to the COVID-19 pandemic on the vegetation cover and to highlight significant changes in the distribution of normalized difference vegetation index (NDVI) before and after the containment period, as well as to identify the areas most affected by these changes. The results highlight significant fluctuations in the distribution of vegetation cover, including a decrease in water area and variations in the categories of bare soil, sparse, medium-dense and dense vegetation. Using NDVI as an indicator of vegetation health, changes before and after the confinement period were highlighted. These results highlight the impact of anthropogenic disturbances such as confinement on plant ecosystems, and underline the importance of continuously monitoring vegetation cover for sustainable natural resource management and biodiversity preservation. With climatic conditions in Morocco stagnating in the two years following containment, the climatic factor is now set aside, and the focus shifts to the impact of reduced human activity.

Keywords: COVID-19, NDVI, Korifla, GIS, remote sensing, vegetation.

INTRODUCTION

Vegetation cover is vital to ecosystem health and human well-being. It plays a crucial role in regulating biogeochemical cycles, such as those of water and carbon, and contributes to the preservation of biodiversity by providing essential habitat for many species. In addition, it acts as a natural barrier against soil erosion and protects farmland from extreme weather events (Allen et al., 2015). Monitoring vegetation cover using remote sensing technologies has become an essential practice to better understand its evolution over time and space (Gonzalez et al., 2018). This approach is essential for the sustainable management of natural resources and the preservation of the environment, as it enables to track the evolution of vegetation cover over time and space, which would be impossible to achieve using traditional field methods alone. This ability to observe vast areas on a regular and consistent basis gives us a more complete and accurate picture of the changes that occur as a result of human activity.

By understanding how vegetation cover evolves, environmental challenges such as deforestation, desertification or climate change, can be better anticipated and responded and also the areas at risk of degradation can be detected, allowing implementation of appropriate conservation measures to protect these fragile ecosystems.

The main aim of this study was to analyze the impact of containment linked to the COVID-19 pandemic on the vegetation cover of the Korifla sub-watershed. Using remote sensing data and spatial analysis, the aim was to highlight significant fluctuations in vegetation cover distribution before and after the containment period. This analysis also made it possible to identify the areas most affected by these changes, and provide empirical data to guide policy decisions on biodiversity conservation and ecosystem preservation. This study built on previous work that has highlighted the significant influence of human activity on plant ecosystems (Allen et al., 2015; Seto et al., 2011). It is based on the idea that anthropogenic disturbances can have profound repercussions on the dynamics of plant cover and its spatial distribution. Global containment in response to the COVID-19 pandemic offered a unique opportunity to assess the impact of human activities on the environment (Attenborough, 2020). This period allowed nature to breathe, regenerate and even show a marked improvement in air quality and biodiversity in certain regions. These observations underline the temporary positive impact of containment on the environment, while highlighting the need for ongoing, sustainable action to maintain these environmental gains over the long term. For this study, the years 1997 to 2019 were used as a pre-containment baseline, while 2020 and 2021 were considered as a post-containment baseline. This temporal analysis will provide a better understanding of the impact of containment on vegetation cover dynamics, and is essential for sustainable natural resource management and environmental preservation. In summary, this research aimed to provide an in-depth understanding of the impact of containment on vegetation cover, highlighting spatial and temporal changes and providing empirical data to guide future actions in sustainable natural resource management and environmental preservation.

Study area

The Korifla sub-watershed is located in the North-West region of Morocco, stretching between latitudes 33°0’0” N and 33°55’0” N, and longitudes 6°25’0” W and 6°55’0” W. It covers an area of 1838 km². The Oued Korifla, which crosses the sub-basin, extends over approximately 1900 km². Geographically, the eastern sub-basin extends over three regions: to the north, the Rabat – Salé – Kénitra region, and to the south, the Beni Mellal – Khenifra region. To the west, it opens onto the Casablanca – Settat region. It includes the following towns: Brachoua, Laghoualem, Lagnadiz, Merchouche, Oulad Boughadi, Oukad Ftata, Rommani (Fig. 1)

MATERIALS AND METHODS

The study of vegetation cover in the Korifla sub-watershed relies on the use of remote sensing and geographic information systems (GIS),

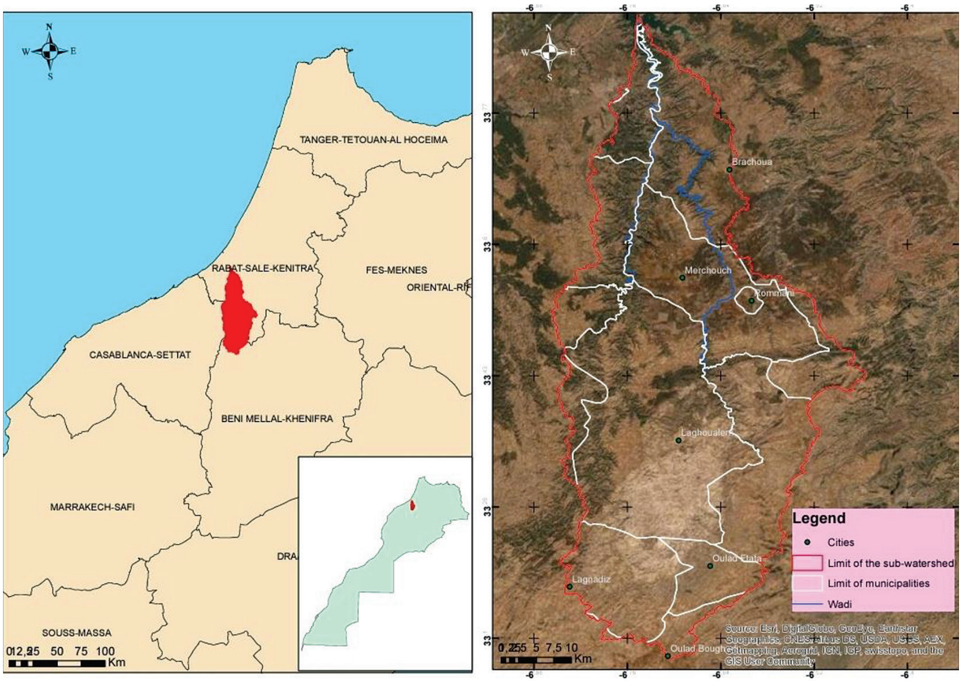

Figure 1. Geographical location of Korifla sub watershed

essential tools widely recognized in the scientific literature for their importance in this field (Gonzalez et al., 2018 ; Justice et al., 2000). These technologies enable detailed analysis and precise mapping of vegetation cover over vast territorial areas, providing a global view of environmental change. In this study, Landsat satellite images were use, downloaded free of charge from Earth Explorer, to produce a time series of normalized difference vegetation index (NDVI) maps. NDVI is an index widely used in remote sensing to assess vegetation density and detect changes in vegetation cover over time (Tucker, 1979). It is calculated from the normalized difference between reflectance in the red and infrared bands of satellite images. The four maps selected for this study correspond to the months of March 1997, March 2019 and March 2020 and March 2021, all characterized by an absence of clouds and good image quality. It should be noted that official containment in Morocco began on March 13th, 2019, making this an important date for analyzing environmental changes linked to the COVID-19 pandemic. The first two NDVI maps, from 1997 and 2019, will be used to establish a description of the vegetation cover prior to the containment period. Comparison of these two maps will highlight changes over the years. The NDVI maps for 2020 and 2021, meanwhile, will provide a description of the post-COVID-19 vegetation cover, making it possible to analyze any variations induced by confinement.

By comparing the results obtained from these maps, it will be possible to deduce the evolution of vegetation cover in the Korifla sub-watershed over the study period. This analysis will also enable to identify the underlying trends and factors contributing to the observed changes, paving the way for a better understanding of the interactions between human activities, environmental phenomena.

NDVI

NDVI can be calculated from images captured by the Landsat satellite, using the functionalities of a geographic information system. The process involves several steps. Firstly, the raw Landsat image data is acquired and imported into the GIS. Next, pre-processing operations are required to improve data quality, including correction for atmospheric effects, dereferencing and radiometric calibration. Afterpiece-processing, the appropriate spectral bands of the image, typically the red and near-infrared bands, are selected. Using these bands, NDVI is calculated for each image pixel by applying the formula:

$$NDVI = (NIR - Red) / (NIR + Red) \quad (1)$$

where: NIR – reflectance in the near-infrared band, Red: reflectance in the red band.

The calculation is performed using the spatial analysis tools available in the GIS. The result is then represented in the form of an normalized difference vegetation index image, which can be used for a variety of vegetation health analyses, such as mapping healthy vegetation zones, detecting environmental stresses, or tracking changes in vegetation cover over time. In summary, by combining the image processing and spatial analysis capabilities of GIS with the data provided by Landsat images, it is possible to efficiently and accurately obtain NDVI to study vegetation at different spatial and temporal scales.

- NDVI 1997

For the 1997 map, it was downloaded from the Landsat 5 satellite, offering 30-meter spatial resolution, and the NDVI calculation equation (Equation 2) was applied. For Landsat 5, the bands required are red (band 3) and infrared (band 4). The application of (Equation 1) for Landsat 5 is:

$$NDVI = (B4\text{-}B3)/ ((B4+B3) \quad (2)$$

- NDVI 2019, 2020 , 2021

For Landsat 8, the bands required are red (band 4) and infrared (band 5). The application is:

$$NDVI = (B5\text{-}B4)/ (B5+B4) \quad (3)$$

The calculation of NDVI in 2020 and 2021 is the same as in 2019, as they belong to Landsat 8 satellite images. Therefore, Equation 3 was applied for these years.

RESULTS

To analyze the NDVI map and determine the minimum value at which vegetation cover begins, it is important to understand that NDVI is an index used to assess the amount of chlorophyll in vegetation. It is calculated by subtracting the reflectance in the red band from the reflectance in the infrared band, then dividing the result by the sum of the two reflectances. Typically, NDVI values range from -1 to 1, where values close to 1 indicate dense, healthy vegetation, while values close to -1 indicate an absence of vegetation, such as water or bare soil.

To determine the minimum value at which vegetation cover begins, the distribution of NDVI values on the map need to be examined. In general, a threshold NDVI value close to 0 can be used to distinguish between vegetated and non-vegetated areas. However, this threshold value can vary according to vegetation type and local environmental conditions. According to Jones (2020), the different NDVI classes are defined as follows (Table 1): dense vegetation, corresponding to NDVI values above 0.6, indicating high vegetation density; moderately dense vegetation, encompassing NDVI values between 0.4 and 0.6, representing moderate vegetation density ; sparse or dispersed vegetation, grouping NDVI values between 0. 2 and 0.4, characterizing less dense or dispersed vegetation; bare ground, which includes NDVI values less than or equal to 0.2, indicating an absence or very low density of vegetation, leaving the ground largely covered; and finally, water.

NDVI data for the years 1997 and 2019, shown in maps (a) and (b) respectively, provide an overview of vegetation density trends in the study area. In 1997 (Fig. 2a), the distribution of areas per km² is as follows: 9 km² for water, 341 km² for bare soil, 1085 km² for sparse vegetation, 386 km² for moderately dense vegetation, and 17 km² for dense vegetation. In 2019 (Fig. 2b), the areas per km² are distributed as follows: 8 km² for water, 507 km² for bare soil, 1260 km² for sparse vegetation, 63 km² for medium-dense vegetation, and 0 km² for dense vegetation. A comparison between the two years (Table 2) reveals several significant changes: a 166 km² increase in bare soil area, a 175 km² increase in sparse vegetation area, a 323 km² decrease in medium-dense vegetation area, and a significant decrease in dense vegetation area, from 17 km² in 1997 to 0 km² in 2019. The maps for 2020 and 2021 (Fig. 3) show significant changes in the spatial distribution of the different land cover categories. Between 2020 and 2021, the area of water decreased by 2 km². There was also a marked reduction of 389 km² in the area of bare soil. Sparse vegetation has also decreased, with a drop of 111 km² between the two years. In contrast, the area of moderately dense vegetation increased significantly, by 502 km². No change was observed in the area of dense vegetation. These trends suggest significant variations in environmental conditions (Table 3). NDVI analysis (Fig. 4) shows a slight but steady decrease in water surface area between 1997 and the post-COVID-19 years. The percentages show a downward trend, from 0.49% in 1997 to 0.33% in 2021. This decrease may reflect changes in environmental conditions or land use. It should be noted that despite this trend, the area under water remains relatively small, representing less than 0.5% of the total area in recent years. Analysis of the data reveals significant fluctuations in bare soil area over the period studied. In 1997, the proportion of bare soil was 18.55%, and then rose sharply to 27.58% in 2019 and 29.92% in 2020. However, in 2021, this trend was reversed, with a notable decrease to 8.76%. An examination of sparse vegetation reveals fluctuations in its coverage between 1997 and the post-COVID-19 years. In 1997, this category represented 59.03% of the total area, rising to 68.55% in 2019. In 2020, this proportion fell slightly to 63.17%, and then continued its downward trend to reach 57.13% in 2021. These variations indicate potential changes in vegetation density over time, likely influenced by various environmental factors.

Table 1. Occupancy type with values for each NDVI Jones class (2020)

NDVI values	Type of occupation
NDVI < 0	Water
NDVI ≤ 0.2	Bare soil
0.2 < NDVI ≤ 0.4	Sparse vegetation
NDVI ≤ 0.6	Moderately dense vegetation
NDVI > 0.6	Dense vegetation

Analysis of medium-dense vegetation reveals significant variations in its area between 1997 and the post-COVID-19 years. In 1997, this class accounted for 21% of the total area, but has decreased considerably to 3.43% in 2019. In 2020, the proportion of medium-dense vegetation increased slightly to 6.47%, then rose sharply to 33.79% in 2021. These variations indicate drastic changes in vegetation density over time. Analysis of dense vegetation reveals significant results, with a relatively small area in 1997, representing just 0.92% of the total area. However, this vegetation class was not observed in 2019, 2020, or 2021, where it recorded values of 0%. Vegetated land represents areas characterized by a variable density of vegetation, ranging from dense forests to grasslands or farmland. The presence of vegetation plays a crucial role in the regulation of

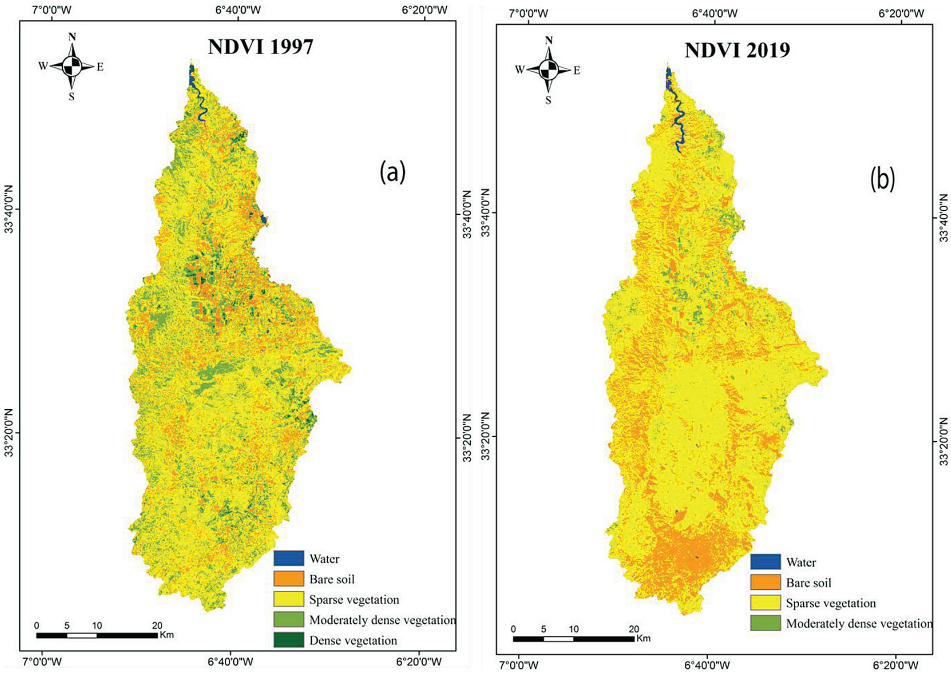

Figure 2. Normalized difference vegetation index (NDVI): (a) map in 1997 (b) NDVI map in 2019

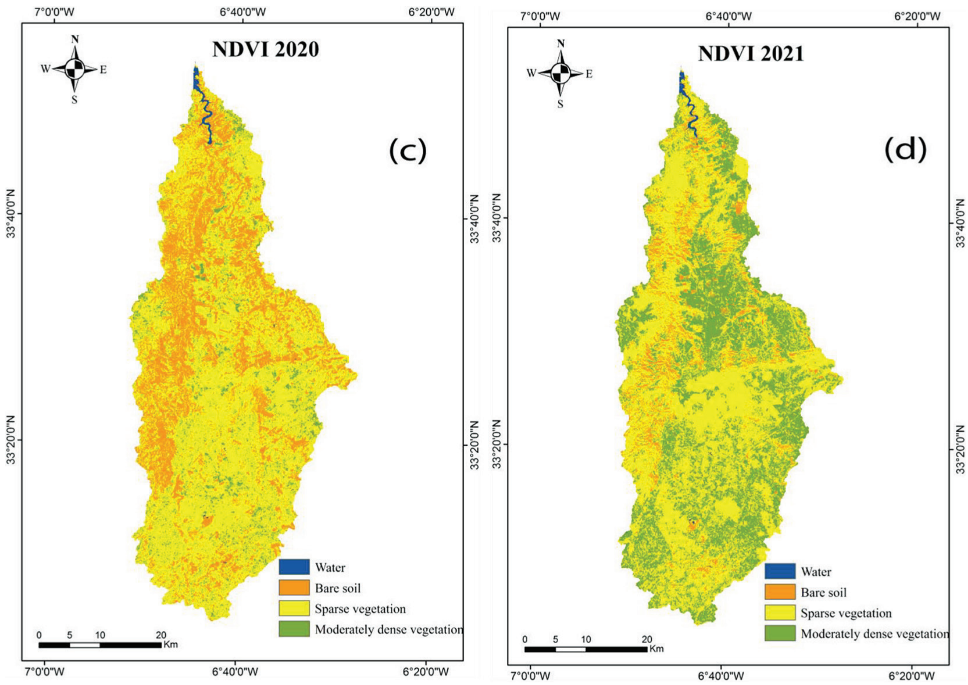

Figure 3. Table 3. NDVI during and after confinement (c) NDVI map in 2020 (d) NDVI map in 2021

Table 2. NDVI comparison between 1997 and 2019

Classes NDVI	1997		2019	
	Area km^2	%	Area km^2	%
Water	9	0.49	8	0.44
Bare soil	341	18.55	507	27.58
Sparse vegetation	1085	59.03	1260	68.55
Moderately dense vegetation	386	21.00	63	3.43

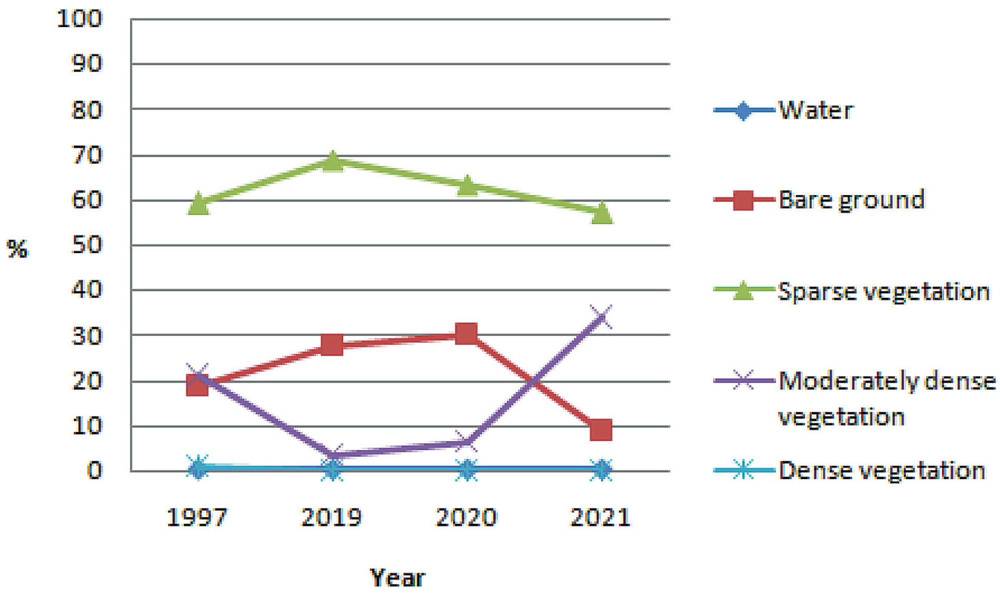

Figure 4. Distribution of land use type

biogeochemical cycles, soil conservation, local climate regulation, and the provision of habitats for wildlife. The NDVI map of the Korifla sub-watershed for the years 1997, 2019, 2020, and 2021 provides an overview of the evolution of vegetation distribution in this region over time. Each map shows the distribution of vegetation in two distinct classes: bare land and land covered by vegetation.

DISCUSSION

From the results obtained, it is possible to deduce the state of post-confinement vegetation cover. Overall, the trends observed indicate significant changes in vegetation distribution and density over time. The steady decrease in water area and the marked fluctuation in bare soil cover suggest changes in environmental conditions and/or land use. Sparse vegetation (Fig. 5b) showed a slight decrease in coverage but remains predominant nonetheless. In contrast, moderately dense vegetation (Fig. 5a) showed significant variations, from a notable decrease in 2019 to a marked increase in 2021. This could reflect changes in agricultural practices or other environmental factors influencing vegetation density. Finally, the complete absence of dense vegetation observed in the post-confinement years suggests major disturbances in the local environment, such as deforestation or urbanization. These results underline the complexity of post-containment environmental dynamics and the need for ongoing monitoring to assess long-term impacts on ecosystems. According to the field visit, areas devoid of vegetation cover, known as bare ground, include surfaces such as bare soil, exposed mineral areas, urbanized areas, or artificial surfaces. In the field, vegetation density can be assessed by taking several indicators into account:

- Plant height: as mentioned by Smith (2010), plant height is an important indicator. Dense vegetation will have taller plants than less dense vegetation.
- Plant spacing: in line with the research by Jones et al. (2015), plant spacing is also significant. Dense vegetation will show little spacing, while less dense vegetation will have more space between plants.
- Number of plant layers: Based on the observations of Brown (2018), the number of plant layers can be a key indicator. Dense vegetation may have several superimposed plant layers, while less dense vegetation will have fewer layers.
- Difficulty of movement: As pointed out by Garcia et al. (2020), ease of movement through vegetation is an important factor. If movement is difficult due to branches or dense foliage, it is likely that the vegetation is dense.
- Light observation: in line with the studies by Taylor et al. (2017), observing the amount of light penetrating through the canopy is a reliable indicator. Low sunlight penetration probably indicates extremely dense vegetation.

Figure 5. Example of moderately dense vegetation (a) example of sparse vegetation (b) where: a) (33.563187, -6.754204) / 25 March 2021; b) (33.655524,-6.729059) / 25 March 2021

It is not necessary to have all these points to determine whether vegetation is dense. Each of these indicators can be used individually or in combination with others to assess vegetation density. Some may be more relevant or easier to observe in certain situations than others. By integrating these observations, it is possible to obtain an accurate estimate of vegetation density in the field.

Analysis of the diagram (Fig. 6) reveals no significant improvement in cumulative rainfall from 2019 to 2021. In terms of precipitation, a slight variation from one year to the next was noted. In 2019, total annual precipitation was 130 mm, and then fell slightly in 2020 to 120 mm. However, in 2021, precipitation rose again to 125 mm. Overall, although the figures fluctuate, there is no clear upward or downward trend in precipitation over the years. Temperatures, on the other hand, seem to be following a more consistent trend. In 2019, the average annual temperature was 18.9 °C. It then rose in 2020 to 20.1 °C, indicating an increase of 1.2 °C. However, in 2021, the temperature dropped slightly to 19.7 °C, representing a decrease of 0.4 °C compared to 2020. Despite this slight drop, the average temperature remains higher than in 2019.

In summary, while precipitation fluctuates slightly from year to year with no clear trend, temperatures show an overall upward trend over the three-year period.The improvement in the vegetation index in 2021, despite less favorable climatic conditions than in 2019, suggests a notable influence of other factors, notably human activity. The years 2020 and 2021 were marked by less favorable climatic conditions, with slightly lower precipitation and rising or stable average temperatures compared to 2019. This trend suggests that climatic variations are not the only determinant of the vegetation index. One plausible

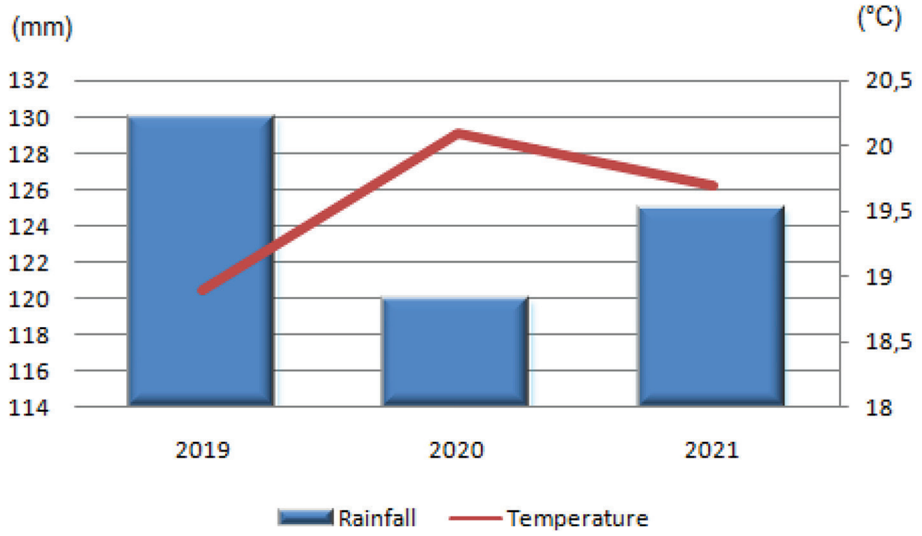

Figure 6. Cumulative annual rainfall and mean annual temperature at the national level
Source: Crop growth monitoring system (CGMS-Morocco)

explanation lies in the containment measures employed during this period, which have probably reduced human activity, including land use and pollution. This reduction in anthropogenic impact may have encouraged better growth and maintenance of vegetation cover, contributing to the improved vegetation index in 2021.

CONCLUSIONS

In conclusion, this study highlighted the significant impact of containment related to the COVID-19 pandemic on vegetation cover in the Korifla sub-watershed. Through the analysis of remote sensing and geographic information system data, significant fluctuations in the distribution of vegetation cover were observed, including a decrease in water area and variations in the categories of bare soil, sparse, moderately dense and dense vegetation. The steady decrease in water area, the marked fluctuation in bare soil cover, and the variations in vegetation density over time suggest changes in environmental conditions and/or land use. These results underline the importance of closely monitoring plant ecosystems and taking appropriate measures to ensure their preservation and sustainable management of natural resources. By analyzing the impact of containment linked to the COVID-19 pandemic on the Korifla sub-watershed, it was possible to observe significant fluctuations in the distribution of vegetation cover, confirming the influence of human activities on plant ecosystems. Remote sensing data and spatial analyses enabled to identify the areas most affected by these changes, providing the data to guide policy decisions on biodiversity conservation and ecosystem preservation. In addition, this study highlighted the unique opportunity that containment has offered to assess the impact of human activities on the environment. The observations made during this unprecedented period underlined the urgent need for concerted action to preserve the environment for future generations, and this research provided valuable empirical data to guide policy decisions on biodiversity conservation and ecosystem preservation. It also highlighted the need for ongoing monitoring and appropriate measures to maintain the environmental gains observed over the long term.

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