Remote Sensing used to monitor the effect of droughts on water levels in the water reservoirs in the region of Andalucia in Spain

by

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Summary

The study discusses a research conducted by Jasper Welgemoed from Technische Universiteit Delft for a course called Earth Observations, focused on monitoring the impact of droughts on water reserves in Andalucia, Spain. The motivation for the study arose during my visit to Andalucia, where I observed extensive droughts affecting water reserves, a critical issue for the region.
Research Question and Area of Interest: The primary research question addresses the effects of droughts on water reserves in Andalucia over the last five years. The study focuses on Andalucia due to its status as the driest region in Spain, with water levels at 20.42% of capacity. I aim to raise awareness and prompt more effective government action to prevent a more catastrophic water crisis.
To assess the impact of droughts, I employ remote sensing in the Visual Spectrum to measure the total surface area of the water reservoirs and the Near Infrared Spectrum to measure specifically the Normalized Difference Vegetation Index (NDVI), to measure the health of vegetation, which is indicative of drought conditions. The study uses Sentinel-2 satellite data, selecting the five largest water reserves for analysis: Iznajar, La Breña II, Guadalcacin, Andevalo, and Negratin.
The study utilizes a temporal resolution of one measurement per month over the past five years, totalling 60 data points. For spatial resolution, the Sentinel-2 L2A satellite with a resolution of 10m for visual bands and 20m for NDVI is employed, meeting the requirements for accurately measuring changes in water surface.
The results indicate a negative trend in the surface area of the water reserves over the five-year period, with an average slope of -1.7921 km^2/year for the five largest reservoirs. The NDVI data shows a decreasing trend, suggesting a decline in vegetation health. The calculated average slope for NDVI is -0.012/year, indicating a steady deterioration of vegetation conditions.
The findings highlight the severity of the drought problem in Andalucia. The average annual loss of water surface area poses a significant threat, potentially leading to complete depletion of the largest reservoir, Iznajar, within four years. The decrease in NDVI further underscores the escalating impact on the droughts.
The study concludes that Andalucia is experiencing a water crisis, worsened by delayed government action. The predictions based on the observed trends suggest a bleak outlook, emphasizing the need for urgent measures to address water scarcity and prevent further environmental and societal consequences.
Recommendations based on the findings could include immediate water conservation measures, more aggressive policies to combat drought, and sustainable water management practices. Additionally, the study advocates for proactive government intervention to mitigate the impending crisis and protect both the environment and the residents of Andalucia.
The study acknowledges the limitations of NDVI, such as its inability to account for artificial watering, which may affect the accuracy of drought assessments. The analysis also assumes that current trends will continue without external interventions.

Contents

Background

Past vacation I visited a very close Spanish friend of mine in Andalucia Spain. When traveling to the Sierra Nevada mountains for a multi-day hike, I looked out the window of the bus and I was stumbled by the amount of lakes that were completely drought out. My friend was not as surprised as I was and told me that those were water reserves that were empty for over five years already. He further told me that if the droughts continued like this, Andalucia will not have enough water for its residents within a couple of years. This would be catastrophic for the residents and environment of Andalucia. This shook me and therefore I am interested in researching how these droughts have evolved and how it affected the water level in the water reserves in the area of Andalucia over the past 5 years and predict a possible trend for the coming years to write out an advice to the government of Andalucia.

The government is slowly taking action against the droughts, but according to my friend, positive thinking of the government has made the government act way too late and too slow. Therefore my objective of this study is to raise awareness to the Andalucian government on the seriousness of the drought problem in the hope that the government will act quicker and more efficiently so they can possibly prevent a water crisis in Andalucia.

Research Question

How have the droughts in Andalucia affected the water reserves for the inhabitants of Andalucia over the last 5 years?

Area of interest

As stated before, the area of interest of this study is the entire region of Andalucia in Spain. The main reason for choosing this area (apart from my friend living there) is a more scientific one. With a water level in its reserves of 20,42%, Andalucia is the driest region in Spain with the lowest water levels in its reserves according to the official water reserve website of Spain (Embalses, 2023).

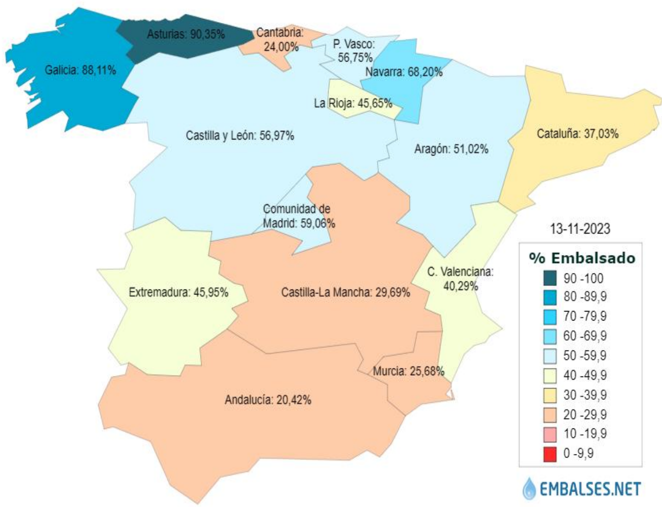


Figure 1, Region of Andalucia (Britannica, 2023)

Figure 2, Water Levels in Andalucia 2023 (Embalses, 2023)

For the rest of this report I will be following the steps described below in figure 3 that will guide me from the chosen issue to the advice as the deliverable.

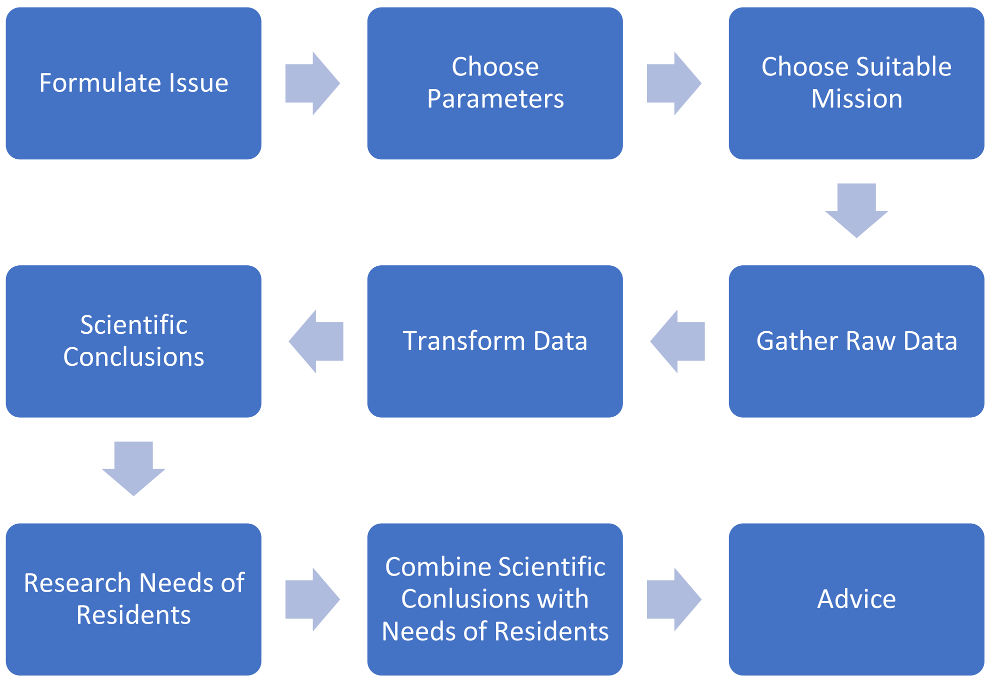


Figure 3, My Research Process

Methodology

In order to find out the effect of the droughts on the inhabitants on the residents of Andalucia. I will need to find out what parameters can be used and if there is already data available to choose from.

I want to find a way to link a unit that measures droughts, to the total surface area of the water reserves (basins). Ideally I would like to make a graph that corresponds the average dryness each year to the total amount of water surface in the basins to predict a trend and predict the water levels over the coming years. To get a general idea of the water levels in Andalucia, I will only look at the five biggest water reserves as they make the biggest impact on the total water level in Andalucia. These are given in table 1.

Water Reserve Name	**Maximum Capacity ($\mathbf{hm^3}$)**
Iznajar	920
La Breña II	823
Guadalcacin	800
Andevalo	634
Negratin	571

Table 1 Five biggest water reserves in Andalucia (Embalses, 2023)

In order to determine the change of the surface area of these basins, we could use visual remote sensing bands. In the EO browser an area of interest can be mapped out and the total surface of that mapped area is displayed. This way I can easily make a polygon around the water surface for different basins at different times and see how much they have changed. For processing this cosmetic datatype, the radiance at ground level is not needed so we do not need optical L2 pre-processing.

During an interview with the father of my friend who is a wine keeper the following came up: "Droughts have high impact on vegetation in Andalucia, especially vineyards have been drought out and more and more harvests are failing. Farmers are not allowed to water their crops anymore due to the water shortage." (de Baker, 2023). So the health of the vegetation could be an indicator for monitoring droughts. I have found a common unit for measuring droughts by looking at the health of vegetation in the area of interest. This is the so-called Normalized Difference Vegetation Index (NDVI). I found that this index has been used in prior researches about droughts in this area by NASA (NASA Earth Observatory, 2023) as well as research about droughts globally by the International Water Management Institute that used the NDVI to monitor droughts in South West Asia (Thenkabail et al., 2004).

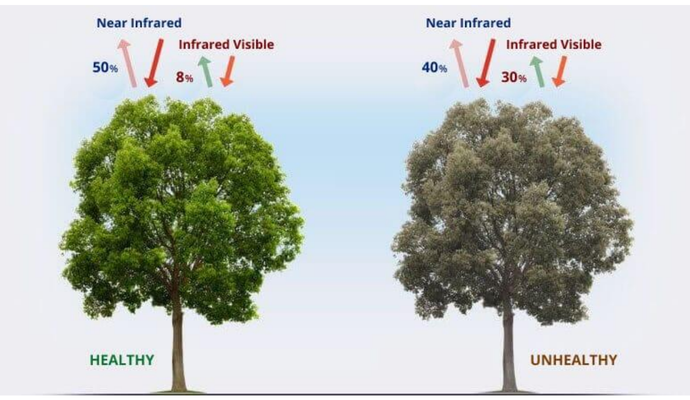


Figure 1 Healthy Vegetation vs Unhealthy Vegetation Reflectance (EOS Data Analytics, 2023)

The NDVI is used in passive remote sensing and uses Near Infrared and Red wavelengths to measure the change in reflectance of the chlorophyll structure in vegetation canopies. This process can be seen in figure 1. The higher the amount of chlorophyll the healthier the vegetation. Chlorophyll strongly absorbs visible light while the cellular structure of the vegetation strongly reflect near-infrared light (EOS Data Analytics, 2023).

The value range of the NDVI is -1 to 1. Negative values of NDMI correspond to water. Values around zero (-0.1 to 0.1) generally correspond to barren soil . Values between 0.2 and 0.4 represent shrubs and grassland, while high values represent temperate and tropical rainforests. To calculate the NDVI, Sentinel-2 uses the Near Infrared B8 band and the red B4 band in the following calculation (Sinergise, 2017).

$$NDVI = \frac{B8 - B4}{B8 + B4}$$

I will gather data of the NDVI in Andalucia over the past five years and. The NDVI is also dependent on cloud coverage as clouds increase the NDVI due to its water content and harvest times due to vegetation not being available. So for simple normalizations to evaluate the temporal evolution of this parameter, it requires absolute atmospheric corrections for the cloud coverage.

Spatial Resolution

The spatial resolution has to be big enough such that we can accurately measure the change in water surface of the smallest water basin in Andalucia. The smallest water basin in the area of Andalucia is 49hectare. Which is around 700m by 700m (Embalsas, 2023).

So any spatial resolution bigger than that will suffice. For the visual spectrum the Sentinel-2 L2A uses bands 4, 3 and 2. Which correspond to a spatial resolution of 10 meters (figure 2). Which is well within our requirements.

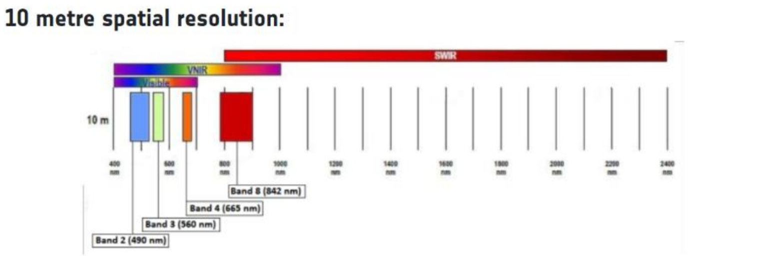


Figure 1: SENTINEL-2 10 m spatial resolution bands: B2 (490 nm), B3 (560 nm), B4 (665 nm) and B8 (842 nm)

Figure 2 Spatial Resolution Visual (Sentinel-Hub, 2023)

For measuring the NDVI the Sentinel-2 L2A uses a combination of the optical bands (B8-B4)/(B8+B4) as can be seen below. This results in a spatial resolution of 20 meters (figure 3) which is again well within our requirements as we do not require to measure the dryness on the accuracy level of the water surface resolution.

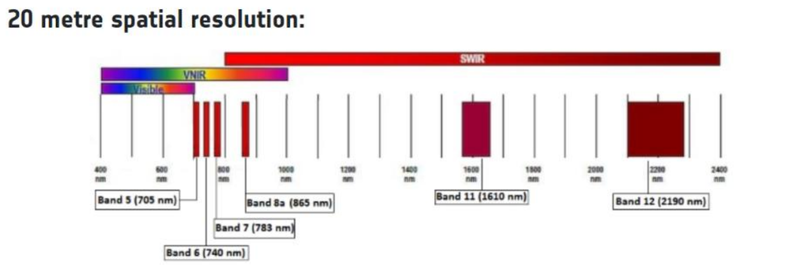


Figure 2: SENTINEL-2 20 m spatial resolution bands: B5 (705 nm), B6 (740 nm), B7 (783 nm), B8a (865 nm), B11 (1610 nm) and B12 (2190 nm)

Figure 3 Spatial Resolution Near-Infrared (Sentinel-Hub, 2023)

Temporal Resolution

The NDVI and the water level of these water basins differ not only on a yearly basis, in fact they can differ multiple times per day! In order to get a sufficient view on the yearly change, I want to monitor the NDVI and the surface of the water levels one time per month for the past 5 years. This way we can average out the influence of the seasons. This way we will get 12 data points per year and 60 data points for the total five years which we can combine to get an average on both NDVI and the water surface which we can then use for our analysis of the trend for the coming years. The Sentinel-2 L2A has a temporal resolution of 5 days so that is well within our requirements.

Orbit

The Sentinel-2 has a sun-synchronous orbit. This minimizes the effect of big variations in shadows on the ground. The orbital altitude lies around 786 kilometres with an inclination of 98.62 degrees. Together with a Mean Local Solar Time at the descending node of 10:30AM it finds balance in the trade-off between enough solar illumination and minimalizing the potential cloud coverage (Sentinel-Online, 2020).

Platform

After doing some research on the suggested platforms by our professor. I have found that the platform EO Browser provides sufficient data and coverage of making use of the Sentinel-2 L2A Satelite that are suitable for our chosen observables NDVI and the visual field. The website of Embalsas will help me gather data on certain characteristics of the water reserves.

Results

An example calculation for the visual determination of change in surface area of reservoir Iznajar is provided below. The rest of the results for the other four reservoirs are provided in appendix A,B,C,D,E. I have made an accurate polygon around the water reserve where water was visible. On the top right of the EO browser, the total area of the drawn polygon would be given. This step is repeated once per month for five years. From that data a graph could be made with a trendline. Via the “compare” option, I could lay multiple time frames besides each other to have an immediate comparison of the change in surface area like in figure 5 and 6.

Figure 5 Surface Area of Iznajar Reservoir in November 2018

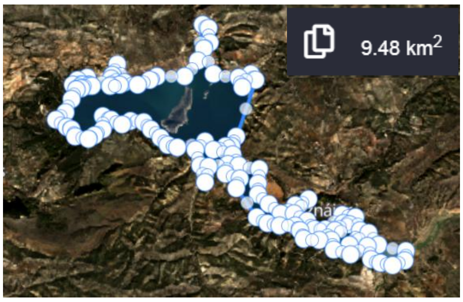
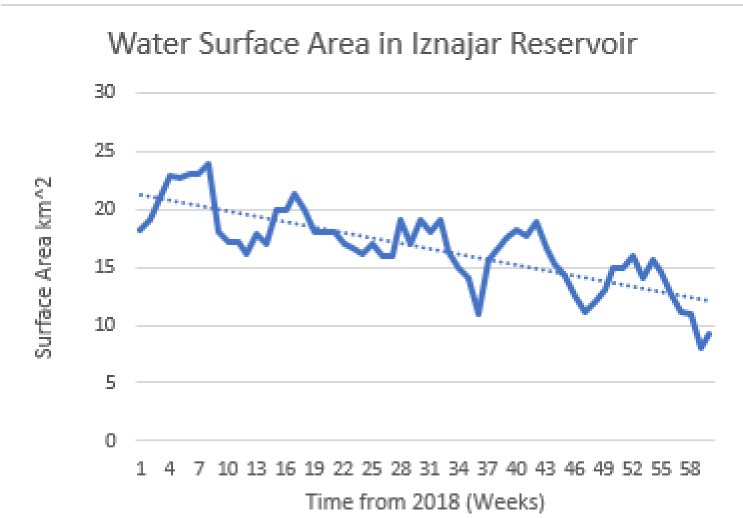


Figure 4 Surface Area of Reservoir Iznajar in November 2023

A graph with a trend line could be made from the values in Appendix A (Graph 1). The same steps have been performed for reservoir La Breña II, Guadalcacin, Andevalo and Negratin. The results can be seen in Appendix B, C, D and E respectively. We see a somewhat linear regression in surface area over 5 years for each of the reservoirs. The slope of the regression line has been calculated via Excel via the slope function of our values and can help us to make a prediction of the water levels in the coming years (Table 2).

Graph 1 Variation in Surface Area of Iznajar Water Reserve from 2018-2023



Reservoir	**Slope** $\left(\frac{\mathbf{km^2}}{\mathbf{year}}\right)$
Iznajar	-1.8468
La Breña II	-1.4964
Guadalcacin	-1.7064
Andevalo	-2.0052
Negratin	-1.9056
Average	**-1.7921**

Table 2 Trend line slopes for each reservoir

We see a somewhat sinusoidal relationship happening within each year, this can be explained by the fact that the water levels are season dependent with its minimum during mid-summer times and maximum at the end of the winter. Though the total trend is still negative. So this shows indeed that there is a decrease in water in Andalucia as expected.

Figure 6 Area of interest for NDVI

For determining the overal effect of the droughts on the vegetation health, we have used the NDVI. In EO Browser we selected the area of interest to be the entirety of Andalucia (Figure 6). Then I selected the available satellite data of that area. I made three selections of three different cloud coverages as this greatly influences the NDVI. Three different plots are given below. In figure 7 you can see the plotted data from the NDVI in the selected area over 5 years with 0-100% cloud coverage. You can see that it is pretty noisy. So it might be worth to look at some lower levels of cloud coverage where the trends are still visible. Luckily the EO browser had an in-built filter, to filter out the data for lower cloud coverages. So in figure 8 you can see the same data but with 10% cloud coverage. I have downloaded the data to Excel and filtered out the anomalies manually to get an overview of a possible trend line within the

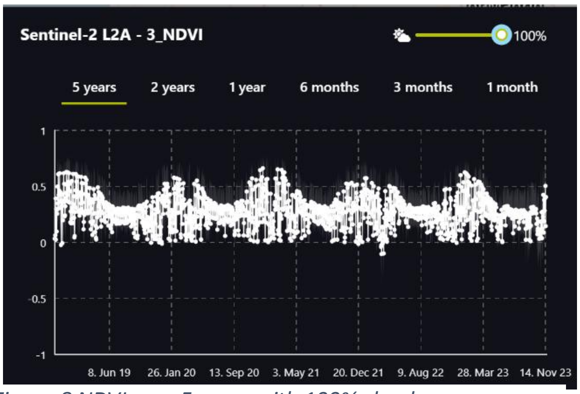


Figure 8 NDVI over 5 years with 100% cloud coverage

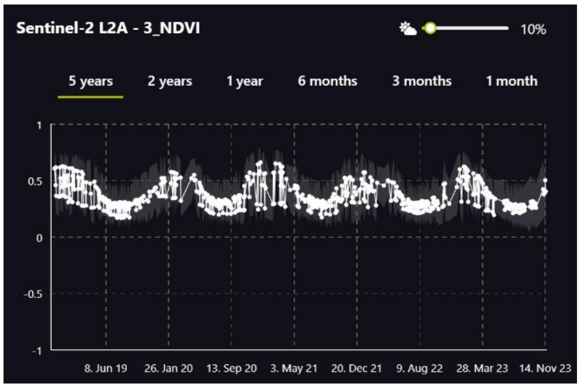


Figure 7 NDVI over 5 years with 10% cloud coverage

data points. A snapshot of the resulting data is given in Appendix F. For further calculations, only the mean value of the time intervals are interesting as they fluctuate quite a lot and there is quite some noise still due to the clouds. In figure 25 of appendix F, the filtered data can be seen from 0-10% cloud coverage. From that data, the mean values per month have been taken from column D in Excel to filter out any fluctuations caused by seasons or other anomalies. From that data, the mean value per year is determined. This way we can make a prediction again of the trend for the coming years. The results are presented below.

Year	**Mean Value**
2018	0.3527
2019	0.3510
2020	0.3411
2021	0.3381
2022	0.3018
2023	0.2911
Average Slope (1/year)	-0.012
Prediction for 2024	0.2791
Prediction for 2025	0.2671

Table 3 Mean NDVI Values per year in Andalucia

Discussion

So exactly how serious is the drought problem in Andalucia? As can be seen from the results, the average loss of water surface area per year is around 1.80 $\frac{\mathrm{km}^2}{\mathrm{year}}$ for the five biggest reservoirs. Knowing the slope and the end-value of the surface of each reservoir; if this trend would continue, that would mean that the largest water reservoir (Iznajar) would have completely depleted within four years. The smallest active reservoir has a current surface area of around $2\mathrm{km}^2$ and is therefore likely to complete deplete within one year (Embalses, 2023). This doesn't even take into account the two reservoirs Sierra Boyera and Puebla de Cazalla that have already completely depleted. As well as the 23 reservoirs that have less than 10% of their level filled (Embalses, 2023). According to larger data sets from Embalses, the level of water has went from 30% to less than 20% only in the last year. This effect can be even seen more clearly over the past five years as in figure 9 and 10. By Spanish laws, each individual living in Andalucia should be provided with 200 litres of water each day (Murcia, 2023). With the new restrictions this is 5% less, so 190 litres. In Andalucia currently live 8.6 million people. So this would lead to 1720 million litres of water in total. According to the official website of the water reservoirs in Spain, the current total amount of water available in the reservoirs is $2449\mathrm{hm}^3$ which translates to 2449000 million litres of water. With a quick calculation you can see that this leads to $\frac{2449000000000}{1720000000} \approx 1424$ days left of water if no significant increase in water levels will be seen in the near future. This is around 4 years. This is also the time that, following my predictions, the water level will be completely depleted from the most reservoirs. So in that way the results lead to a somewhat accurate prediction. But it is not looking good.

Figure 10 Sentinel-2 Imagery of Guadalcacin in November 2018

Figure 9 Sentinel-2 Imagery of Guadalcacin in November 2023

The decrease in NDVI per year cannot so clearly be seen from figure 8 alone, but the filtered data in Excel does show us a clear yearly decrease in the NDVI with 0.012 per year. With this, predictions are made for 2024 and 2025 as can be seen in table 3. As the scale tells us, values between 0.2 and 0.4 are shrubs and grasslands, if this value is nearing 0.2, the vegetation becomes barren (Sinergise, 2017). Now the NDVI cannot take into account artificial watering of the vegetation. So there is no direct relationship between the numbers of the NDVI and the dryness of that area as an area might be very dry, but is artificially watered. What we do know though is that the government has imposed restrictions on artificial watering of crops due to the water shortage in 2021 (Murcia, 2023). Interestingly enough, the biggest drop in the mean NDVI value can be seen exactly in that year. So this might actually tell us something about the natural dryness taking over as people could not artificially water. The same result can be seen from Near Infrared Imagery taken by Sentinel-2 in the years 2021 and 2023 after the artificial watering restrictions where asserted as in figure 11 and 12. So it seems like the pattern of Andalucia becoming dryer and dryer seems to continue. This would mean that with the current rate, crops would become completely barren within 6 years. Now this seems like a long time to go, but this rate doesn't take into account the years where artificial watering was still allowed. The decrease in NDVI purely after the watering restrictions was around 0.025 per year, so that is twice as fast! Together with the results that water becomes less and less available, I would assume that the artificial watering restrictions will be held in place for the coming years. So that would mean that all crops will be barren withing less than 3 years if no additional measures are taken. This predicts a continuation of the droughts in Andalucia for the coming years, which can not be permitted, because the inhabitants will come short of water, which would be catastrophic.

Figure 12 NDVI NIR Imagery from Sentinel-2 in Andalucia in November 2021

Figure 11 NDVI NIR Imagery from Sentinel-2 in Andalucia in November 2023

Conclusion

Andalucia is heading towards a water crisis. The government has acted to late and my results predict an even further increase in dryness for the coming years and a predict a serious water shortage within 4 years or less if no immediate action is taken. The use of remote sensing, specifically Sentinel-2 satellite data, helps us to understand these environmental changes over time. The evidence presented through remote sensing, particularly the analysis of surface area changes and the Normalized Difference Vegetation Index (NDVI), paints a concerning picture of a looming water crisis. The observed negative trend in the surface area of the five largest water reserves, coupled with a consistent decline in NDVI values, underscores the severity of the situation. If these trends persist, there is a real and imminent risk of complete depletion of most of the reservoirs within just a few years.

As a recommendation to the government I would imply a need for immediate water conservation efforts, robust policies combating drought, and the development of a framework towards sustainable water management practices. However, there are limitations to the study, particularly in its reliance on NDVI, which may not fully capture the complexities of droughts, especially in the context of artificial watering. Additionally, my prediction assumes a continuation of current trends, neglecting the potential external interventions or unforeseen changes, but that doesn't take away the severity of the situation. The impending water crisis requires more decisive and accelerated action from the government to secure the region's water resources and protect its inhabitants and ecosystems.

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Appendix A Results Iznajar

B	C	D	E	F	G	H	I
18.76	Nov-18		16.76	Nov-20		12	Nov-22
19.32			17.28			13.58	
20.12			17.87			14.93	
21.21			18.62			15	
22.12			19.22			16.14	
22.21			20.12			16.41	
21.13			19.11			15	
20.31			18.31			14.14	
19.12			17.18			13.26	
18.12			16.2			11.18	
17.61			15.18			10.33	
16.42			14			9.48	
17.83	Nov-19		14.43	Nov-21		9.66	Nov-23
18.61			15.13				
19.24			16.11				
20.16			17.5				
21.12			18.31				
21.71			18.71				
20.21			17				
19.74			16.22				
18.52			15.34				
17.53			14.26				
16.12			12.51				
			11.16				

Table 4 Water Surface Area Iznajar Reservoir from 2018 to 2023 monthly measurement table

Figure 13 Sentinel-2 Imagery of Iznajar in 2018

Figure 14 Sentinel-2 Imagery of Iznajar in 2023

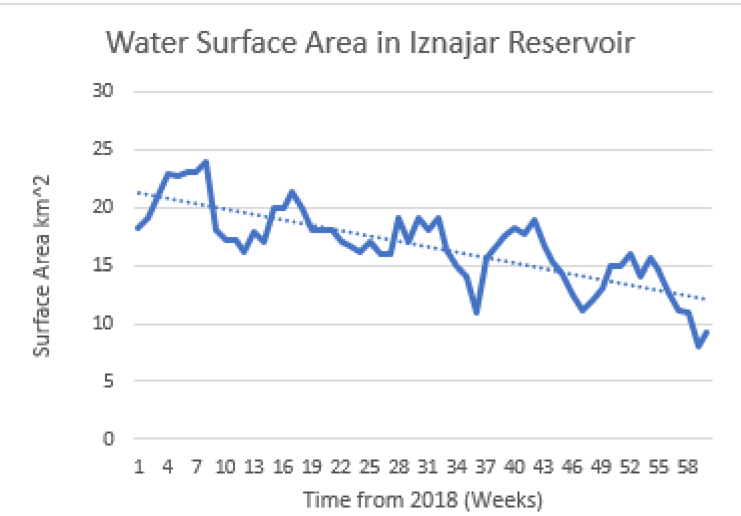


Figure 15 Variation in Surface Area of Iznajar Water Reserve from 2018-2023

Appendix B Results La Breña II

C	D
Nov-18	18.25
	18.81
	19.61
	20.7
	21.61
	21.7
	20.62
	19.8
	18.61
	17.61
	17.1
	15.91
Nov-19	17.32
	18.1
	18.73
	19.65
	20.61
	21.2
	19.7
	19.23
	18.01
	17.02
	15.61

C	D
Nov-20	16.25
	16.77
	17.36
	18.11
	18.71
	19.61
	18.6
	17.8
	16.67
	15.69
	14.67
	13.49
Nov-21	13.92
	14.62
	15.6
	16.99
	17.8
	18.2
	16.49
	15.71
	14.83
	13.75
	12
	10.65

C	D
Nov-22	11.49
	13.07
	14.42
	14.49
	15.63
	15.9
	14.49
	13.63
	12.75
	10.67
	9.82
	8.97
Nov-23	9.15

Table 5 Water Surface Area La Brena II Reservoir from 2018 to 2023 monthly measurement table

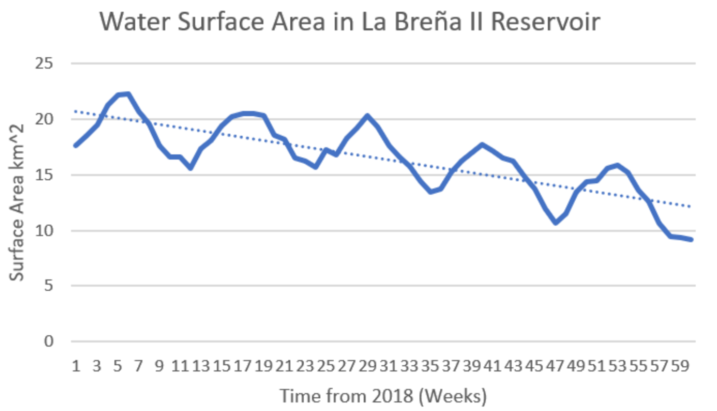


Figure 16 Variation in Surface Area of La Brena II Water Reserve from 2018-2023

Figure 18 Sentinel-2 Imagery of La Brena II in 2018

Figure 17 Sentinel-2 Imagery of La Brena II in 2023

Appendix C Results Guadalcacin

E	F
Nov-18	13.06
	13.9
	14.9
	16.7
	17.6
	17.7
	16.1
	15
	13.02
	12.02
	11.99
	11
Nov-19	12.73
	13.51
	14.8
	15.6
	15.9
	15.9
	15.7
	14
	13.6
	11.9
	11.6

Nov-20	11.1
	12.7
	12.24
	13.7
	14.6
	15.7
	14.7
	13
	12
	11.19
	9.9
	8.9
Nov-21	9.1
	10.6
	11.6
	12.4
	13.1
	12.61
	11.9
	11.6
	10.24
	9.16
	7.41
	6.06

Nov-22	6.9
	8.9
	9.83
	9.9
	11.04
	11.31
	10.6
	9.04
	8
	6.08
	4.9
	4.8
Nov-23	4.56

Table 6 Water Surface Area Guadalcacin Reservoir from 2018 to 2023 monthly measurement table

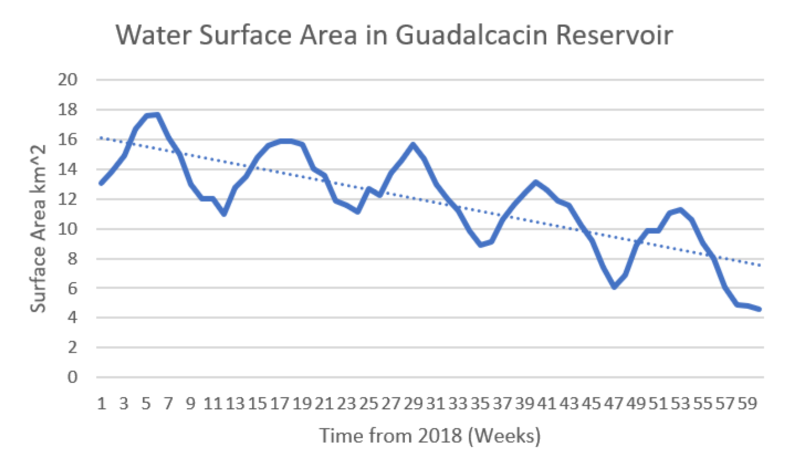


Figure 19 Variation in Surface Area of Guadalcacin Water Reserve from 2018-2023

Figure 20 Sentinel-2 Imagery of Guadalcacin in 2018

Figure 21 Sentinel-2 Imagery of Guadalcacin in 2023

Appendix D Results Andevalo

G	H
Nov-18	10.56
	11.4
	12.4
	14.2
	15.1
	15.2
	13.6
	12.5
	10.52
	9.52
	9.49
	8.5
Nov-19	10.23
	11.01
	12.3
	12.4
	12.4
	12.4
	13.2
	11.5
	11.1
	9.4
	9.1
Nov-20	8.6
	9.4
	9.4
	10.4
	11.4
	13.4
	11.4
	10.5
	11.4
	8.69
	7.4
	6.4
Nov-21	4.4
	8.1
	9.1
	9.9
	10.6
	10.11
	9.4
	9.1
	7.74
	6.66
	4.91
	3.56
Nov-22	4.4
	6.4
	7.33
	7.4
	9.4
	9.4
	8.1
	7.4
	4.4
	3.58
	2.4
	1.4
Nov-23	1.6

Table 7 Water Surface Area Andevalo Reservoir from 2018 to 2023 monthly measurement table

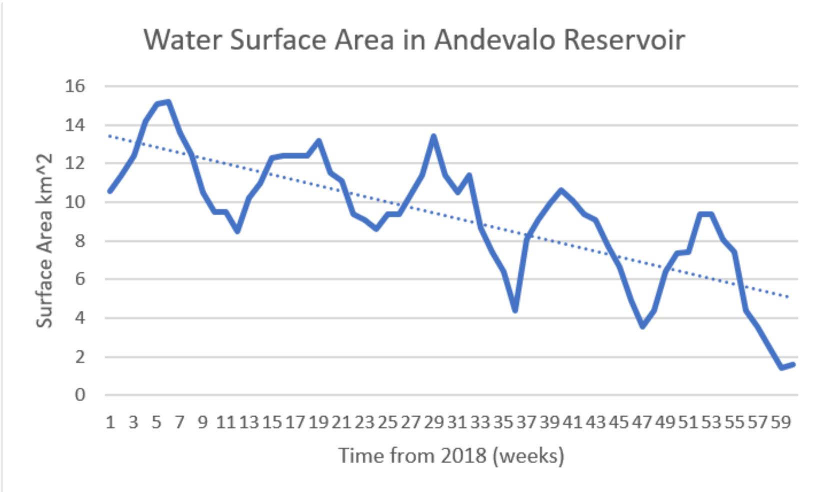


Figure 22 Variation in Surface Area of Andevalo Water Reserve from 2018-2023

Figure 24 Sentinel-2 Imagery of Andevalo in 2018

Figure 23 Sentinel-2 Imagery of Andevalo in 2023

Appendix E Results Negratin

I	J
Nov-18	12.56
	13.4
	15.4
	17.2
	17.1
	17.4
	17.4
	18.4
	12.52
	11.52
	11.49
	10.5
Nov-19	12.23
	11.4
	14.3
	14.4
	15.72
	14.4
	12.4
	12.4
	12.4
	11.4
	11.1

Nov-20	10.6
	11.4
	10.4
	10.4
	13.4
	11.4
	13.4
	12.5
	13.4
	10.69
	9.4
	8.4
Nov-21	5.4
	10.1
	11.1
	11.9
	12.6
	12.11
	13.27
	11.1
	9.74
	8.66
	6.91
	5.56

Nov-22	6.4
	7.4
	9.33
	9.4
	10.4
	8.4
	10.1
	8.9
	7
	5.58
	5.4
	2.4
Nov-23	3.6

Table 8 Water Surface Area Negratin Reservoir from 2018 to 2023 monthly measurement table

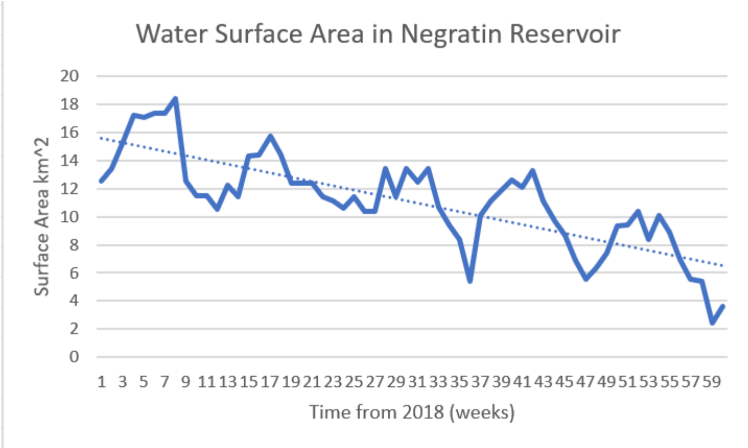


Figure 25 Variation in Surface Area of Negratin Water Reserve from 2018-2023

Sentinel-2 Imagery of Negratin in August 2018

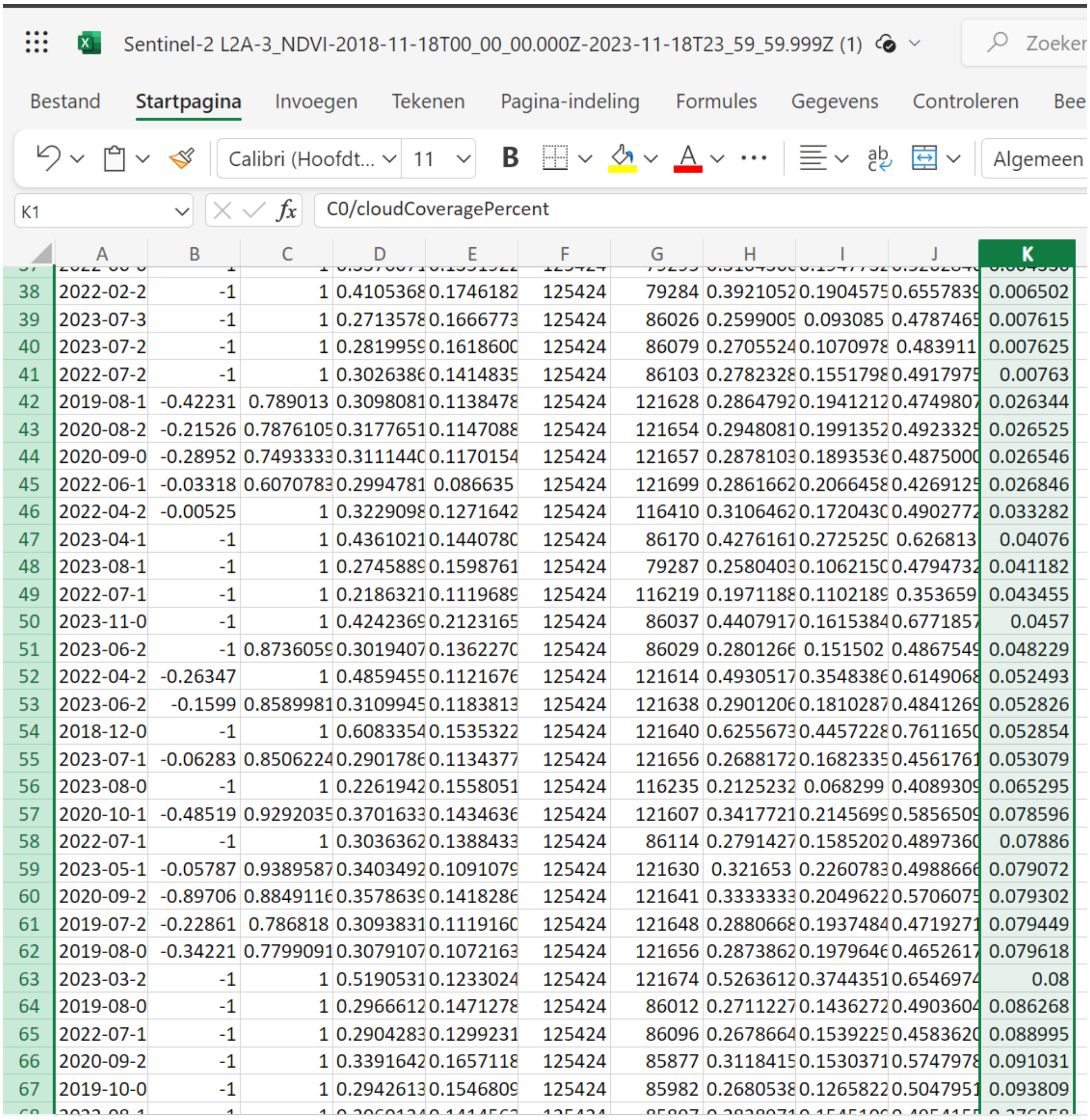
Sentinel-2 Imagery of Negratin in August 2023

Appendix F Results NDVI Snapshot

Sentinel-2 L2A-3_NDVI-2018-11-18T00_00_00.000Z-2023-11-18T23_59_59.999Z (1)

	A	B	C	D	E	F	G	H	I	J	K
1	C0/date	C0/min	C0/max	C0/mean	C0/stDev	C0/sample	C0/noData	C0/median	C0/p10	C0/p90	C0/cloudCoveragePercent
2	2018-11-1	-1	1	0.034044	0.092002	125424	86027	0.00774	-0.00452	0.084841	88.04985151153609
3	2018-11-2	-1	1	0.064027	0.1463125	125424	79356	0.0134212	-0.00883	0.1885369	66.91412694277994
4	2018-11-2	-1	1	0.3918619	0.2967233	125424	121640	0.4061433	0.0254981	0.764103	19.159619450317113
5	2018-11-2	-0.10332	0.9966749	0.0245846	0.048438	125424	116175	0.0108733	-0.00868	0.067524	94.78862579738335
6	2018-11-2	-1	1	0.2970456	0.2597791	125424	85784	0.2148298	0.040365	0.6849256	47.75731584258303
7	2018-11-2	-1	1	0.097259	0.1537825	125424	79114	0.0345726	-0.01026	0.30396	76.31397106456515
8	2018-11-2	-0.29132	1	0.2901494	0.1450678	125424	121528	0.2531813	0.1295317	0.4984615	89.81006160164272
9	2018-11-2	0	1	0.2560964	0.1211057	125424	116407	0.2356575	0.1186283	0.4169625	80.96928024841971
10	2018-11-2	-1	1	0.4982990	0.1942563	125424	86020	0.5058099	0.2463179	0.7439875	18.175819713734498
11	2018-11-3	-1	1	0.3487547	0.2420061	125424	79398	0.3219730	0.041936	0.6900584	19.31951505670704
12	2018-12-0	-1	1	0.6083354	0.1535322	125424	121640	0.6255673	0.4457228	0.7611650	0.052854
13	2018-12-0	-0.65116	1	0.3012717	0.1186288	125424	116181	0.2830809	0.1685923	0.4627408	52.472141079735955
14	2018-12-0	-1	1	0.4230088	0.1721309	125424	85787	0.4161435	0.2055120	0.6557658	58.52107879001984
15	2018-12-0	-1	1	0.4609716	0.1785467	125424	79155	0.4445362	0.2415094	0.7094812	3.864358425727816
16	2018-12-0	-1	1	0.6170531	0.1547639	125424	121547	0.636912	0.4530340	0.7671046	0.6190353366004638
17	2018-12-0	-1	1	0.3656635	0.1440716	125424	116361	0.3453860	0.2026854	0.5612446	1.0040825333774699
18	2018-12-0	-1	1	0.3615574	0.2383417	125424	85967	0.3422999	0.058761	0.6951643	52.193527130801066
19	2018-12-1	-1	1	0.4457817	0.1747086	125424	79314	0.4258302	0.2340852	0.6945680	17.05270006506173
20	2018-12-1	-0.06331	0.061497	-0.02269	0.0156397	125424	121621	-0.02701	-0.0382	0.000224	100
21	2018-12-1	-1	1	0.3212122	0.1790689	125424	116208	0.3243317	0.040024	0.5480563	15.614149305555507
22	2018-12-1	-1	1	0.3669324	0.2494967	125424	85889	0.350586	0.0416326	0.7002217	24.047046920450125
23	2018-12-1	-1	1	0.4279056	0.1761579	125424	79310	0.4186379	0.2125824	0.6677647	19.633950644056164
24	2018-12-1	-0.07158	0.1248016	-0.00689	0.0156826	125424	121597	-0.00869	-0.0222	0.0101769	51.68539325842689
25	2018-12-1	-1	1	0.3592843	0.1497736	125424	116283	0.3407142	0.189567	0.5583107	4.868176348320752
26	2018-12-1	-1	1	0.1973314	0.1628051	125424	85811	0.1634999	0.0216	0.4159536	97.42256329992654
27	2018-12-2	-1	1	0.373501	0.2121065	125424	79405	0.3671852	0.089053	0.6648333	19.27682044372986
28	2018-12-2	-1	1	0.6176231	0.1468145	125424	121545	0.6412894	0.464896	0.7543674	1.0827532869296215
29	2018-12-2	-1	1	0.3612496	0.1411877	125424	116338	0.3410981	0.2011483	0.5512232	2.751485802333269
30	2018-12-2	-1	1	0.5223516	0.1989040	125424	85786	0.5571030	0.2503805	0.7524154	7.338917200665955
31	2018-12-2	-1	1	0.2337216	0.1480897	125424	79283	0.2030047	0.073141	0.4390901	92.45357

Figure 26 NDVI of Andalucia over 5 years with 100% cloud coverage



Sentinel-2 L2A-3_NDVI-2018-11-18T00_00_00.000Z-2023-11-18T23_59_59.999Z (1)

K1 C0/cloudCoveragePercent

	A	B	C	D	E	F	G	H	I	J	K
38	2022-02-2	-1	1	0.4105368	0.1746182	125424	79284	0.3921052	0.1904575	0.6557839	0.006502
39	2023-07-3	-1	1	0.2713578	0.1666773	125424	86026	0.2599005	0.093085	0.4787465	0.007615
40	2023-07-2	-1	1	0.2819959	0.1618600	125424	86079	0.2705524	0.1070978	0.483911	0.007625
41	2022-07-2	-1	1	0.3026386	0.1414835	125424	86103	0.2782328	0.1551798	0.4917975	0.00763
42	2019-08-1	-0.42231	0.789013	0.3098081	0.1138478	125424	121628	0.2864792	0.1941212	0.4749807	0.026344
43	2020-08-2	-0.21526	0.7876105	0.3177651	0.1147088	125424	121654	0.2948081	0.1991352	0.4923325	0.026525
44	2020-09-0	-0.28952	0.7493333	0.3111440	0.1170154	125424	121657	0.2878103	0.1893536	0.4875000	0.026546
45	2022-06-1	-0.03318	0.6070783	0.2994781	0.086635	125424	121699	0.2861662	0.2066458	0.4269125	0.026846
46	2022-04-2	-0.00525	1	0.3229098	0.1271642	125424	116410	0.3106462	0.1720430	0.4902772	0.033282
47	2023-04-1	-1	1	0.4361021	0.1440780	125424	86170	0.4276161	0.2725250	0.626813	0.04076
48	2023-08-1	-1	1	0.2745889	0.1598761	125424	79287	0.2580403	0.1062150	0.4794732	0.041182
49	2022-07-1	-1	1	0.2186321	0.1119689	125424	116219	0.1971188	0.1102189	0.353659	0.043455
50	2023-11-0	-1	1	0.4242369	0.2123165	125424	86037	0.4407917	0.1615384	0.6771857	0.0457
51	2023-06-2	-1	0.8736059	0.3019407	0.1362270	125424	86029	0.2801266	0.151502	0.4867549	0.048229
52	2022-04-2	-0.26347	1	0.4859455	0.1121676	125424	121614	0.4930517	0.3548386	0.6149068	0.052493
53	2023-06-2	-0.1599	0.8589981	0.3109945	0.1183813	125424	121638	0.2901206	0.1810287	0.4841269	0.052826
54	2018-12-0	-1	1	0.6083354	0.1535322	125424	121640	0.6255673	0.4457228	0.7611650	0.052854
55	2023-07-1	-0.06283	0.8506224	0.2901786	0.1134377	125424	121656	0.2688172	0.1682335	0.4561761	0.053079
56	2023-08-0	-1	1	0.2261942	0.1558051	125424	116235	0.2125232	0.068299	0.4089309	0.065295
57	2020-10-1	-0.48519	0.9292035	0.3701633	0.1434636	125424	121607	0.3417721	0.2145699	0.5856509	0.078596
58	2022-07-1	-1	1	0.3036362	0.1388433	125424	86114	0.2791427	0.1585202	0.4897360	0.07886
59	2023-05-1	-0.05787	0.9389587	0.3403492	0.1091079	125424	121630	0.321653	0.2260783	0.4988666	0.079072
60	2020-09-2	-0.89706	0.8849116	0.3578639	0.1418286	125424	121641	0.3333333	0.2049622	0.5706075	0.079302
61	2019-07-2	-0.22861	0.786818	0.3093831	0.1119160	125424	121648	0.2880668	0.1937484	0.4719271	0.079449
62	2019-08-0	-0.34221	0.7799091	0.3079107	0.1072163	125424	121656	0.2873862	0.1979646	0.4652617	0.079618
63	2023-03-2	-1	1	0.5190531	0.1233024	125424	121674	0.5263612	0.3744351	0.6546974	0.08
64	2019-08-0	-1	1	0.2966612	0.1471278	125424	86012	0.2711227	0.1436272	0.4903604	0.086268
65	2022-07-1	-1	1	0.2904283	0.1299231	125424	86096	0.2678664	0.1539225	0.4583620	0.088995
66	2020-09-2	-1	1	0.3391642	0.1657118	125424	85877	0.3118415	0.1530371	0.5747978	0.091031
67	2019-10-0	-1	1	0.2942613	0.1546809	125424	85982	0.2680538	0.1265822	0.5047951	0.093809

Figure 27 NDVI in Andalucia over 5 years after filtering between 0-10% cloud coverage