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Department of Arctic and Marine Biology

Changes in Senescence for High Arctic Vegetation

A Study on How Climate Change May Affect Plant Communities

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1 Abstract:

Climate change is predicted to accelerate the closer you get to the poles. And in contrast to more southern regions, which is forecasted to receive increased temperatures and drought, the Arctic is predicted to get both higher temperatures and an increase in precipitation. This means that in the study site for this paper, Adventdalen, on the high arctic island of Spitsbergen, Svalbard, the plant communities, will most likely experience an increase in both temperature and precipitation. This study looks at how three somewhat different plant communities in Adventdalen might respond to an increase in rainfall. The different plant communities are dominated by *Cassiope tetragona*, *Dryas octopetala* and *Salix polaris,* respectively. We aim to see if an experimental increase in precipitation will influence plant senescence in the autumn in the high arctic. In order to be able to see an effect within the realm of possibilities for the future, we chose to increase the amount of precipitation by 90 mm over a period of 6 weeks in the summer, capturing the peak of the growing period and the beginning of the senescence stages for the chosen plant communities.

The results of this study show that an increase in precipitation will prolong the growing season and plant senescence in the study area. The magnitude of the NDVI response to increased soil moisture is plant species specific. The percent decline for NDVI measurements show that the biggest effect was achieved at the *Cassiope* site, where the watered plot had a change in NDVI values of - 22.9%, whereas the ambient plot had a change of – 51.3%. For the *Dryas* site the change in NDVI was for the watered plot – 31.0% and for the ambient plot the change was – 49.4%. For the *Dryas* site the change in NDVI values were the smallest, but still significant, with changes in NDVI for the watered plot at – 37.8% and the ambient plot at – 51.0%.

An elongation of the growing period might give some species an advantage in productivity compared to others, while other species might suffer disadvantages, e.g., if temperatures drop below freezing before the plants have senesced.

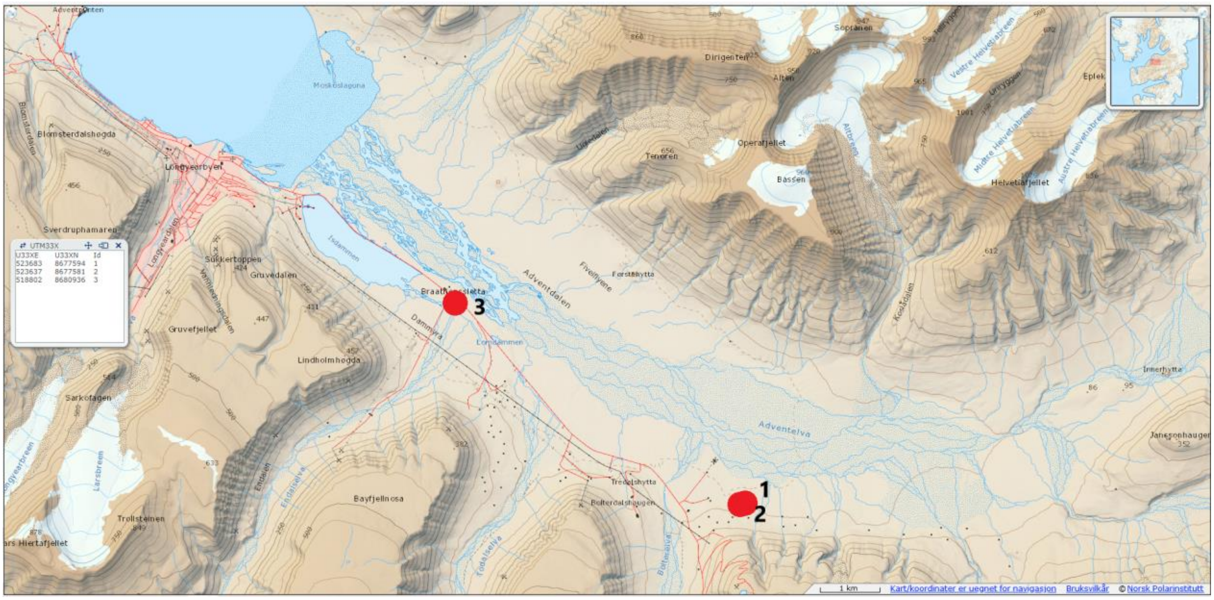
Key words: senescence, precipitation, end of growing season, high arctic vegetation.

2 Introduction:

In order to understand what global climate change in the Arctic will mean for the biodiversity of the world and how fragile ecosystems might respond to a new climate, one needs to look at how the primary producers, the base of the ecosystem, respond to climate change. Circum-polar climate changes more rapidly than any other place on the planet. The high Arctic ecosystem is according to Bintanja & Selten (2014) overall much simpler and more prone to bigger changes than ecosystems closer to the equator, although migratory species enriches the ecosystem in the summer as found by Callaghan, et al., (2013) in their study. But even if the ecosystem is simpler, it holds species found nowhere else on the planet. These species have nowhere to go if the climate of their habitat changes to a point where they can no longer survive. Species found in the high arctic are prone to severe changes in their habitat climate, heavier precipitation, more wind, higher temperatures, and species invasions by non-native species. Even the simple ecosystem of the high Arctic consists of different trophic levels with primary producers as the base of which the higher trophic levels depend on (Stewart et al. (2018)). Therefore, it is of the utmost importance to find out how the primary producers of this area might react to the dramatic changes that is forecasted in regards of circumpolar climate. This study focuses on how the chosen plant communities autumn leaf phenology is affected by an increase in precipitation during the growing period.

2.1 Study area

The study presented in this paper takes place in Adventdalen on Spitsbergen, the largest island of the Svalbard archipelago. Adventdalen is a high-arctic valley at approximately 78° north with a width of 3.5 km – 4 km throughout most of the valley. The annual precipitation in the area is 224.8 mm (average 2011-2020), most of which falls as snow during the fall and winter as reported by Barr (2021). Average annual temperature in the area is -2.4°C (2011-2020) whereas average summer temperature is 5.5°C (Jun-Sept 2011-2020). All weather data has been collected from the Norwegian Centre for Climate Services (seklima.met.no). According to the Norwegian Centre for Climate Services data, the annual precipitation average has increased. Average annual precipitation from 1981 – 1990 was 182.4 mm, whereas average annual precipitation from 2011-2020 was 224.8 mm. The average annual temperature has changed as well, increasing by almost 4 °C from -6.2 °C in the normal period (1981 – 1990) (Førland et. al., 2011) to -2.4°C in the new period (2011 – 2020) (Box, et al., 2019).



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U33XE	U33XN	Id
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Figure 1: Topographical map of the study area. Provided by The Norwegian Polar Institute at https://toposvalbard.npolar.no

Figure 1 shows a topographical map of the study area in Adventdalen, the proximate location of the rack systems is shown by the markers 1, 2 and 3 on the map. Rack 2 *Cassiope* site is nr 1, Rack 4 *Dryas* site is nr 2 and Rack 6 *Salix* site is nr 3.

Table 1: Average annual and summer temperatures and precipitation at Svalbard Airport, numbers from seklima.met.no1

Interval	Average annual temperature (°C)	Average annual precipitation (mm)	Average summer (June-Sept) Temperature (°C)	Average summer (June Sept) precipitation (mm)
1981-1990	-6.2	182.4	3.3	16.7
2011-2020	-2.4	224.8	5.5	22.1

Several studies in the past have found that water, nutrients and temperatures are the main limiting factors in plant phenology (Opala-Owczarek, et al. (2018), Tamstorf et al. (2007), Liu, et al. (2016) and Kemppinen, et al. (2021)) all found similar results regarding the limiting factors of plant phenology. In northwest Greenland, Jespersen et al. (2021) found that warmer temperatures and increased precipitation lead to increased *S. polaris* coverage. Most previous studies on the matter have focused on plant community and soil respiration and productivity or CO_2 flux. Illeris et al. (2003) found in their study that increased precipitation alters plant carbon and respiration.

2.2 Vegetation indices: NDVI

Normalized Difference Vegetation Index (NDVI) is a vegetation indices that measure the relative amount of vegetation and it’s vitality in an area, using near-infrared and red wavelengths that interact with the live plant material. NDVI can indicate the productivity of a plant community, as proven by Gamon, et al. (1995). Knowing that the green color in plants comes from chlorophyll, in which photosynthesis takes place and that photosynthesis creates nutrition for the plant, as well as oxygen as a by-product, from carbon dioxide, water and sunlight. NDVI and plant community productivity does not have an exact correlation, the correlation is relative. Weier & Herring (2000) found for NASA that NDVI utilizes frequencies in the near infrared spectrum and red visible light to calculate how green the patch of vegetation is. The wavelengths used by the NDVI sensors range from 0.4 – 0.7 and 0.7 – 1.1 micrometers. The readings provided from the sensors are what is put into the NDVI equation, and the calculation retrieves a value ranging from – 1 to +1, which is the value of NDVI. The process that makes these readings possible is radiation from the sun, where certain wavelengths of that radiation interact with the vegetation. The radiation that interacts with the vegetation, is the radiation that the NDVI sensor detects. The near infrared radiation is reflected and the visible red radiation is absorbed by the chlorophyll for energy to perform photosynthesis.

For this study NDVI measurements was used to see whether or not additional watering has an effect on the overall vegetation production and vitality of each plant community. The NDVI measurements acts as a proxy for vegetation productivity in this study. An overall increase in NDVI might be caused by a) a higher maximum vegetation productivity or b) an extent of the growing period throughout the Autumn.

2.3 Soil-water-senescence interactions

The properties of the soil in which the plants reside, has a major impact on the ability the roots of the plants have, to access the added water. Finer soil will have a better chance of retaining water than coarser soil, due to, among other factors, Van der Waal forces. Finer soil has greater surface area to retain the water, compared to coarser soil which has more open space in between the particles. All in all, finer soil particles make for worse drainage, compared to coarser soil particles.

Senescence is the term used for when a plant withers and dies. This is usually easily seen with the naked eye as the plant changing in color from green to yellow, red and brown. This is because of the degradation of chlorophyll in the leaves, chlorophyll being the source of the green color of the leaves according to Woo et al. (2018). Drought is one of the factors that expedites the process of senescence (Chen et. al. (2020), Estiarte and Peñuelas (2014). Previously the main focus, of studies, has been on how the phenology of plants during spring and green-up is affected by access to water, this is something we now know quite a bit about. There is not much information and knowledge about how the amount of water accessible to plants, throughout the main growing season, affects the autumn phenology and how it affects the length of the growing season.

Drought stress has proven to affect plant phenology by some plants choosing to forego their leaves during high levels of drought stress to prevent the plants water transport system, xylem, from cavitation (McDowell et. al. (2008)). Cavitation of xylem in time might lead to vegetation death, which is why it is so important for plants to prevent it, by not prioritizing the limited water resources to the vast leaf area of the plant.

The hypothesis is that if water accessibility gets higher for plants in this area, the plants might have a longer growing period and a slower rate of senescence than plants without the same access to water, and that different plant communities react differently to an addition of water. In order to test this hypothesis, three high Arctic plant communities, dominated by *C. tetragona*, *D. octopetala* and *S. polaris*, respectively, were chosen to study how they respond to predicted increase in precipitation.

3 Material and method:

3.1 Field experiment setup

The whole study area consists of ground affected by permafrost and runoff from glaciers. Average summer precipitation in the area is around 23.2 mm (2011-2020), the aim was to increase this substantially but still within the realm of possibilities considering climate change. The plots chosen for this experiment were chosen because of their relatively dry soil and abundance of *S. polaris*. Soil moisture was increased by adding an additional 90 mm of water over the entirety of the experiment. Each watering event added 7.5 mm of water for each experimental (watered) plot, The watered plots were watered twice a week for 6 weeks. This adds up to an additional 90 mm increase in precipitation for the watered plots over the growing period, compared to the control (ambient) plots that only had access to natural rainfall. This is an increase of 50% from the average annual rainfall from 1981 – 1990, which is within the probabilities of what can be expected as a result of climate change in the area.

Figure 2: Watering was done by the help of a standard 10L watering can, equipped with a sprinkler spout to simulate rainfall.

During the experiment there was a total of 21.2 mm of natural rainfall in the area, measurements done by the Norwegian Climate Service Centre (2022). Which means that the watered plots had a total of 111.2 mm of precipitation during the main growing period of 2021 and the ambient plots got the natural rainfall of 21.2 mm during the same period. This amounts to the watered plots receiving about 5 times the amount of water, as the ambient plots.

The water used for watering the plots was collected from streams nearby using a measuring cup and a 10 L watering can which was equipped with a sprinkler spout. The plots were measured out by using a 1m^2 frame with 10cm^2 grids lain on the ground next to the rack setup. The plots were marked in each corner with a nail decorated with red plastic tape for visibility.

3.2 Rack setup

Figure 3: Rack setup with a digital wildlife camera on one of the arms at the top of the installation and an NDVI sensor on the other arm at the top of the installation. 1m^2 plot directly underneath the rack setup within the field of view of both the RGB-camera and NDVI sensor.

A Spectral Reflectance Sensor SRS from METER Group, Inc. was used for NDVI measurements and a 5TM combined Water Content and Temperature Sensors from Decagon Devices, Inc. was used for the soil moisture and soil temperature measurements throughout the project. The RGB photos were taken using a regular digital wildlife camera (RGB-camera).

All the rack systems were equipped with an RGB camera, NDVI sensors, soil moisture sensors and soil temperature each. The cameras and NDVI sensors cover a portion slightly bigger than the plots for the study. Each plot is measuring 1m^2. The three different areas studied were named *Cassiope* site, *Dryas* site and *Salix* site, named after the species dominating in the area. Each site has two racks each, one watered plot and one ambient plot named Rack 2, *Cassiope* site, Rack 4, *Dryas* site and Rack 6 *Salix* site. All sensors were connected to a data storage unit by wires. The wires were taped to the pole of the rack setup to avoid wild reindeer from ripping the wires from the equipment. The cameras operated on their own, storing the pictures on SD cards.

Three areas with somewhat different vegetation composition were chosen and 1 watered plot was set up next to 1 ambient plot. The watered plots were treated with 7.5 liters of water, each, twice a week for 6 weeks during the main growing period. The period of watering occurred between 15. July and 26. August.

The equipment with the data was collected on 16 October, giving data from 13. July to 16. October. Giving measurements for a period of time after the watering events, covering the peak of the growing season and time of senescence for the vegetation.

Vegetation data was collected by subjectively doing a percent cover estimate of 1 m^2 for each species, including bryophytes, soil, stones, and droppings, as well as a frequency cover over 1 m^2 with 10 cm^2 grid for each species.

3.3 Type of data and data treatment

The data collected gave the values used for the predictions made in this paper. The NDVI gives the greenness on a scale from -1 to 1, the soil moisture is given in percent and the temperature in degrees Celsius.

The soil moisture sensor uses an electromagnetic field to measure the moisture content in the surrounding soil. The temperature sensor reads the temperature of the surface of the prong that is inserted into the soil (Decagon Devices, Inc., 2016) .

NDVI is calculated using the following formula:

$$NDVI = \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}}$$

Formula 1: NDVI calculation formula

where ρ_{red} and ρ_{NIR} are percent reflectance in the red and near infrared (NIR) (METER Group, Inc. United States, 2020).

The ambient racks were set up earlier than the watered racks, making the datasets for the ambient plots contain datapoints from a longer period of time compared to the watered datasets. To be able to compare the datasets, data only from dates that appear in both datasets for each area were selected for the study. The datasets were also shortened to only cover the peak of the growing season and senescence. As snow cover interfered with the NDVI readings towards the end of the sampling period.

The sensors for the ambient plots were programmed to collect data 4 times a day, at 08.00, 12.00, 16.00 and 18.00. The sensors for the watered plots were programmed to collect data once every hour throughout the day. Only the data that is taken at the same time for both the ambient plots and the watered plots were extracted from the datasets. For this paper only the data from 12.00 o'clock were considered. Each rack system has 67 data points for NDVI and soil moisture giving about 2 months' worth of data, from 16. July to 20. September.

Each rack system was equipped with an RGB camera, taking pictures 5 times a day, but this data was not used for this paper.

Some of the equipment for Rack 6 malfunctioned, meaning that no data for soil moisture or soil temperature for either the watered nor the ambient plots for this area were collected, but there are NDVI values and RGB photos for all.

The graphical figures and statistical analysis were completed using the programs RStudio (RStudio Team 2021) and Microsoft Excel (Excel version 2021).

Table2: Dates of watering events during the period 17. July to 25. August.

Date	Added water in mm
17.07.2021	7,5
21.07.2021	7,5
24.07.2021	7,5
28.07.2021	7,5
31.07.2021	7,5
04.08.2021	7,5
07.08.2021	7,5
11.08.2021	7,5
14.08.2021	7,5
18.08.2021	7,5
21.08.2021	7,5
25.08.2021	7,5
Total:	90

Table 2 shows the dates and amount of water added throughout the project. All watered plots received a total of 90 mm of extra water during the experiment period. Each watering event included all the watered plots from all the project sites. The water used for each watering event was collected from streams and rivers close to the project sites. This amount of water was chosen to give an increase in soil moisture that is significant and still within the realm of possibilities as to what the plant community might have to endure in future climate.

4 Results:

The vegetation data are presented in figures 3, 4, 6 and 8. Figure 3 shows the plant composition for each plant community. Figures 5, 7 and 9 show examples of the dominating species for each study area site. Each plant community have different cover of live and dead plant material as well as different plant species composition. This affects how the NDVI and soil moisture readings when additional precipitation are added to the watered plots.

4.1 Vegetation data

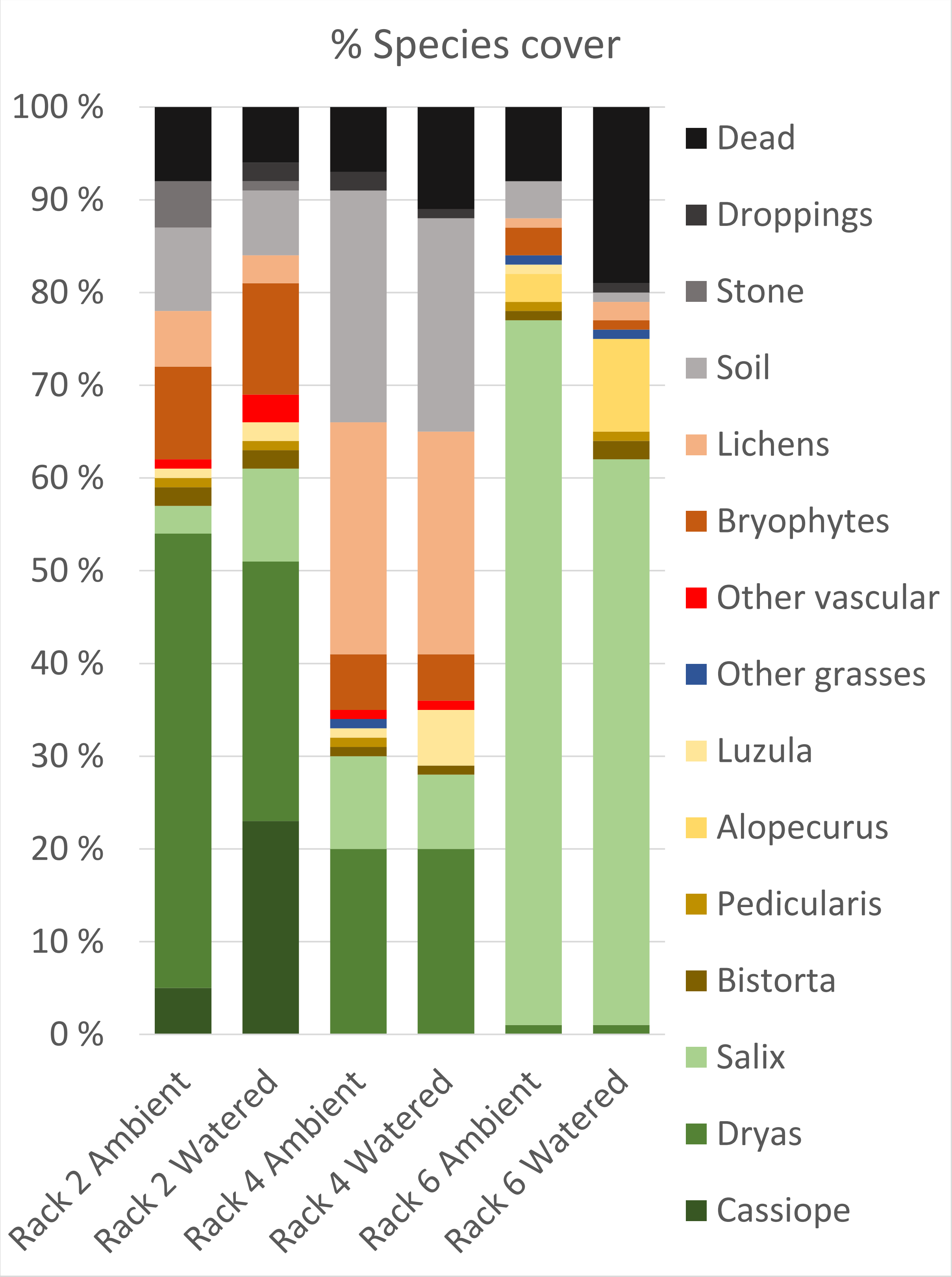

Figure 4: percent cover plant species ambient and watered plots.

Figure 4 shows the species composition of each plant community in this study. It shows that the Rack 2 system is the *Cassiope* plant community, and the abundance of each species found in that area. The Rack 4 system is the *Dryas* plant community and that is the plant community with at least abundance of living plant material. The figure also show that the Rack 6 system is the *Salix* plant community, which also has the highest abundance of living plant material for this study. The figure also shows that the ambient and watered plots, within each plant community, has quite similar plant species composition as a starting point for the experiment.

Table 3: Percent cover of live and dead plant material for each plot in the three plant communities.

Rack	Treatment	Alive%	Dead%
2 - *Cassiope*	Ambient	78	22
	Watered	84	16
4 - *Dryas*	Ambient	66	34
	Watered	65	35
6 - *Salix*	Ambient	88	12
	Watered	79	21

Table 3 shows the percent cover estimates for all living and dead plant material for each plot. It shows the abundance of each plant species, including soil, droppings, stones, lichens and bryophytes. The table shows that a few species are abundant within each plot, and that the vegetation cover is extensive for all three communities. All objects covering the ground in a plot will have an effect on the NDVI readings. It is particularly interesting to see how many percent of the plot consists of non-living material, as this will have a negative influence on the NDVI readings. Mosses have been found to contribute substantially to NDVI readings, immediately following a watering event, depending on what the species of moss is in the plant community. In this area the dominating moss species is *Sanionia uncinata*. For this study all categories above the "Lichens" category are categorized, in the stacked column, as non-living material.

Each watered plot was positioned close to a rack representing the ambient plot. The ambient plots were compared to the watered plot for each species. This makes the study focus on three slightly different plant communities and how each community responds to an increase in soil moisture.

4.1.1 Rack 2: *Cassiope* site

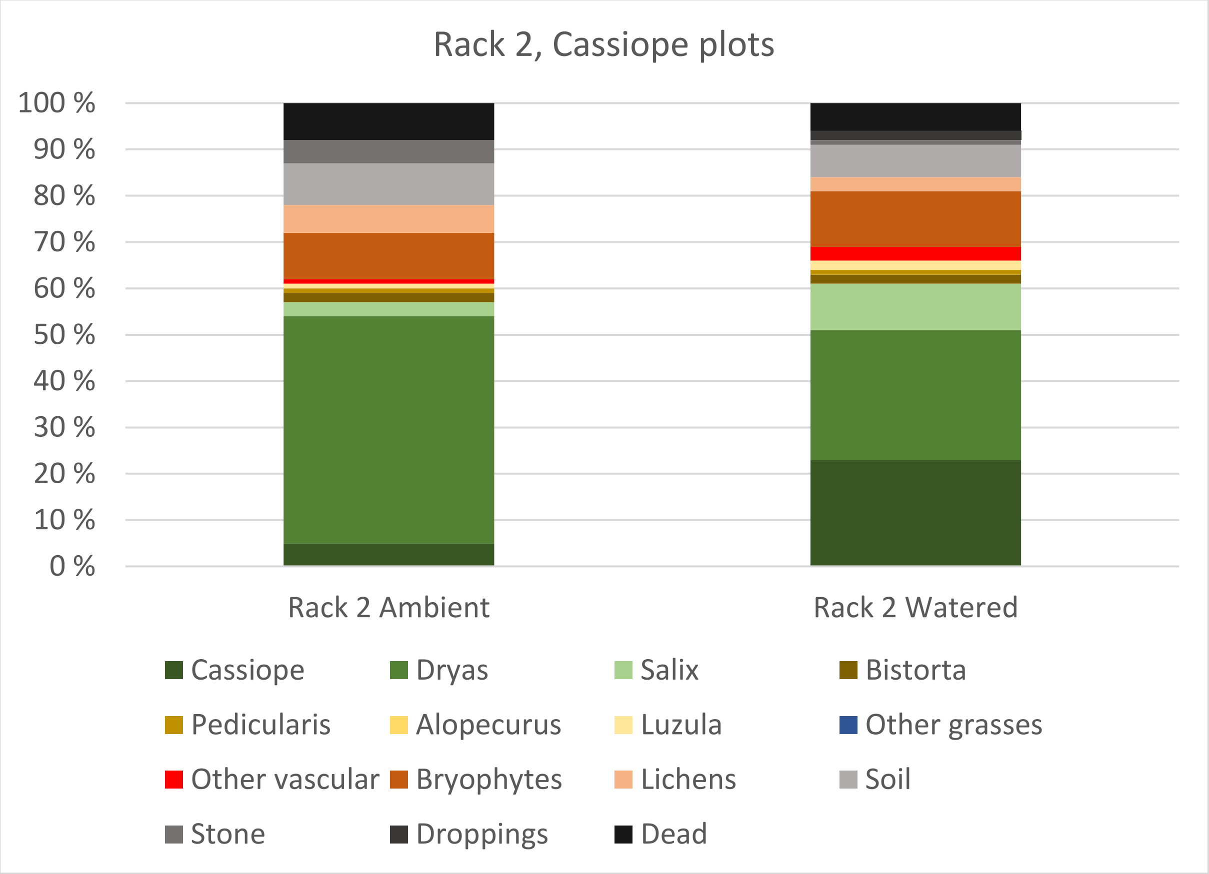

Figure 5: Species composition for Rack 2, ambient and watered plot

Figure 5 shows that the Rack 2 plots are the only plots containing *C. tetragona*, even if *D. octopetala* is abundant at the site, *C. tetragona* is the dominating species for the area. Rack 2 has approximately 78 – 84% live plant material, including lichens and bryophytes. That means that for 16 – 22% of the plot it affects the NDVI value in a negative way, not contributing to any plant productivity.

The difference in living plant material versus dead material is very small for the *Cassiope* site. The difference in *D. octopetala* is on the other hand quite large, with close to twice the abundance of *D. octopetala* in the ambient plot compared with the watered plot. The abundance of *C. tetragona* is on the other hand quite a bit larger for the watered plot compared to the ambient plot with more than four times the amount of *C. tetragona* in the watered plot.

Cassiope tetragona is a perennial dwarf shrub, according to Svalbard flora. The leaves of *C. tetragona* loses their green color during senescence. This will show as a decrease in NDVI values for the species, as NDVI measures the relationship between the red and near-infrared spectra of a plant community.

Figure 6: Cassiope tetragona from the Cassiope plant community.

4.1.2 Rack 4: *Dryas* site

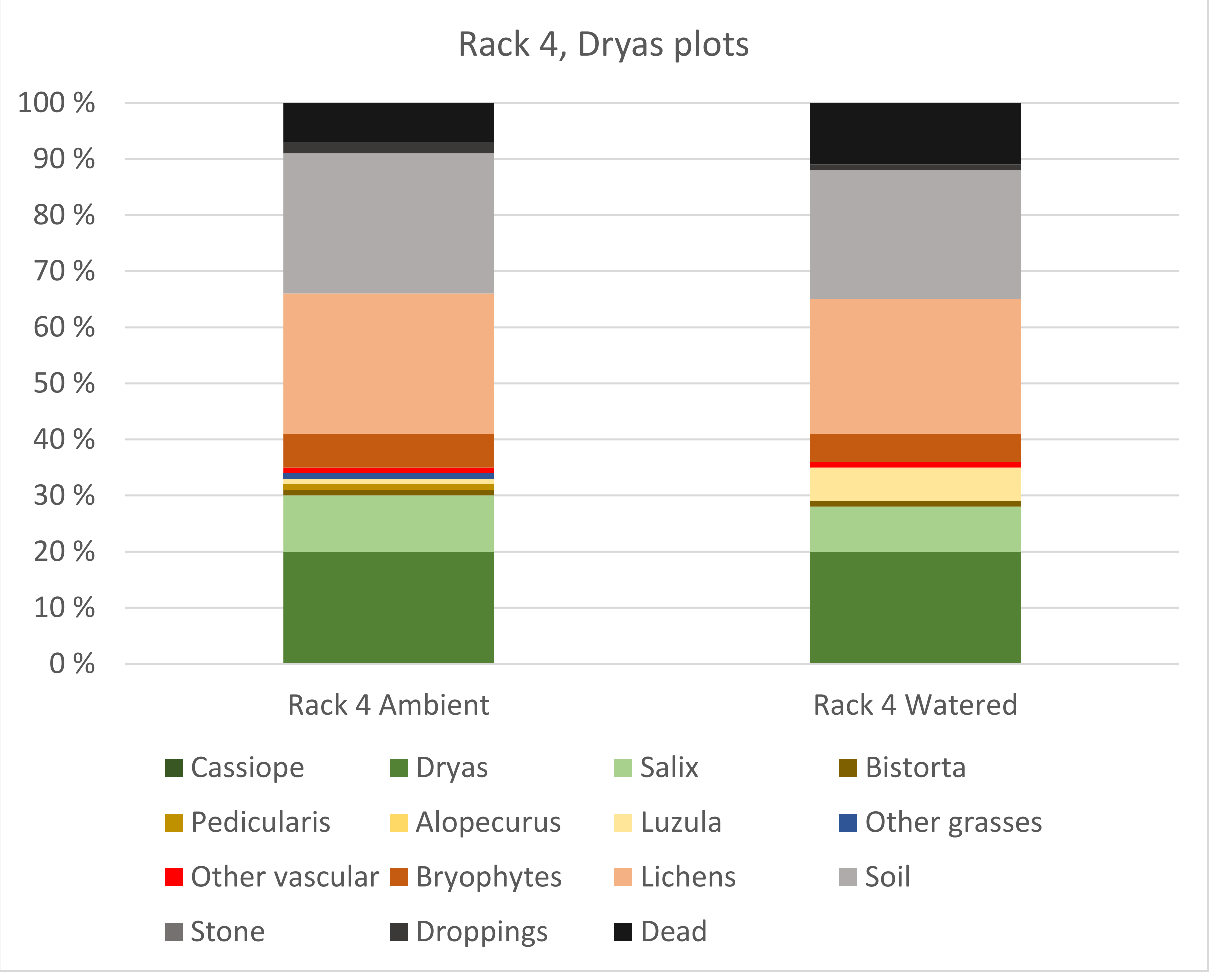

Figure 7: Species composition for Rack 4, ambient and watered plot

Rack 4 is abundant in *D. octopetala*, but does not have any *Cassiope*, this makes Rack 4 the *Dryas* site for this study. Rack 4 has 65 – 66% living plant material in the plots. This gives 34 – 35 % non-living materials for the plots, making the *Dryas* site, the site with the least amount of living plant material in the study.

The ambient and watered plot of the *Dryas* site is quite similar, the only significant difference is that the ambient plot contains "*Pedicularis*" and "Other grasses", whereas the watered plot contains more "*Luzula*" than the ambient plot.

Dryas octopetala is a perennial semi evergreen dwarf shrub. During senescence, the leaves of *Dryas* turn brown and the leaves that have turned grey are the dead parts of the plant. This is recorded as part of the "dead plant material" category in the stacked column chart.

Figure 8: Dryas octopetala from the Dryas plant community.

4.1.3 Rack 6: *Salix* site

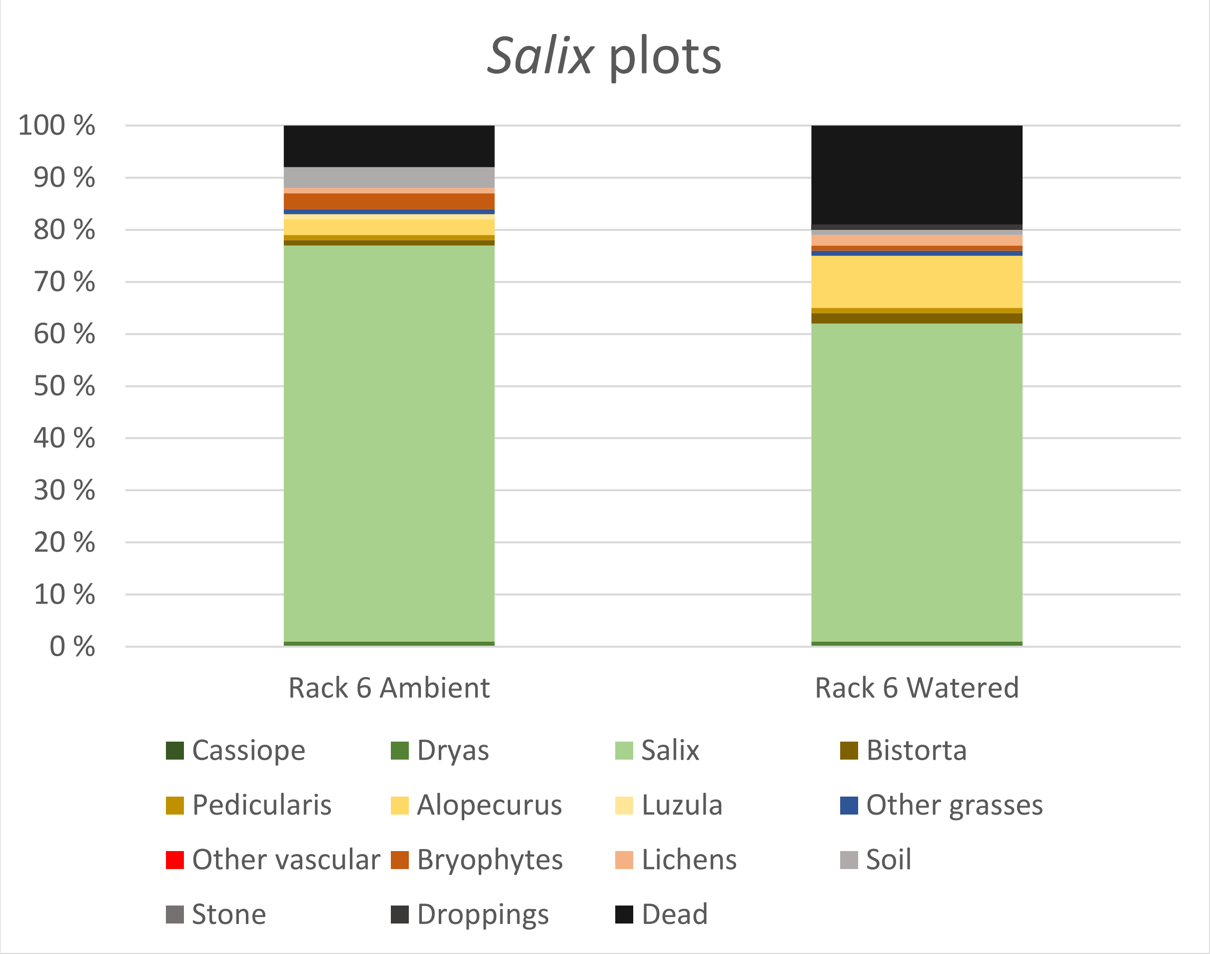

Figure 9: Species composition for Rack 6, ambient and watered plot

Salix polaris is heavily abundant in Rack 6 plots. The *Salix* site consists of 79 – 88 % living plant material and 12 – 21 % non-living material. This makes Rack 6 the site with the highest percentage of living plant material in the study.

For the *Salix* site, the watered plot contains almost twice as much «dead» material as the ambient plot and about 10% less *S. polaris*. The watered plot also contains quite a bit more graminoids than the ambient plot.

Salix polaris is a perennial deciduous shrub, this means that the leaves of the plant turn brown and fall off the plant during senescence. This shows up in the NDVI measurements as a decline in NDVI values. During the installation of the 5TM sensor, some of the *Salix* were damaged, making a part of the plots turn yellow before the actual senescence of the species naturally occur.

Figure 10: Salix polaris from the Salix plant community

Distinction in which species is abundant in each site is important when analyzing the NDVI data provided. This is because each species looks different, they have different shades of green and different size flowers. These differences are all factors that contribute to differences in NDVI values.

Mosses has a rather rapid response in NDVI to precipitation, and Figure 4 shows that moss is present in all 6 plots investigated. This means that the rapid response in NDVI after a watering event might be caused by the abundant bryophyte cover in the plot. As shown by May et al. (2018) in their study.

Cassiope tetragona has a dark green color and thick leaves with small, but abundant, white flowers at the top of the plant. *Dryas octopetala* has a lighter green color and thinner leaves with big white flowers, less abundant than the flowers of *Cassiope*. *Salix polaris* presents as a green food of paired leaves, the flower of *Salix* is relatively small and red in color. *Salix* shows clear yellowing during senescence.

The soil moisture content (%) for the plots is shown in Figure's 11 and 12.

4.2 Environmental data

Figures 11 – 12 show the soil moisture readings for Rack 2, *Cassiope* site and Rack 4, *Dryas* site for the entire period of the project. Figures 13 – 15 show the raw NDVI measurements for all plots studied from the peak of the growing period towards the end of the growing period. Figures 16 – 18 show the NDVI measurements normalized for all plots studied through the study period. Figures 19 – 21 shows the NDVI values for each rack over the period of the project. Figures 22 – 23 show the relationship between the NDVI measurements and the soil moisture for the watered and ambient plots for the *Cassiope* plant community (Rack 2) and the *Dryas* plant community (Rack 4). Figures 24 – 25 show the soil temperatures for the same plots as figures 22 – 23. The black lines and dots represent the different data for the watered plots and the red lines and dots represent the different data for the ambient plots. The data collection started at the peak of the growing season, making the NDVI values start out high, keeping somewhat stable through the growing season with a decline over time. This is because the plants senescence towards the end of the growing season, making the previously green plants turn yellow and brown. NDVI gives a value of how red wavelengths and near-infrared (NIR) wavelengths interact with the plant material. For vibrant green vegetation, the red wavelengths will be highly absorbed by the plant material, and the NIR will be reflected. As plants senescence NIR will be absorbed more, and the red wavelengths will be reflected more, this is what causes the NDVI values to decline.

4.2.1 Soil moisture

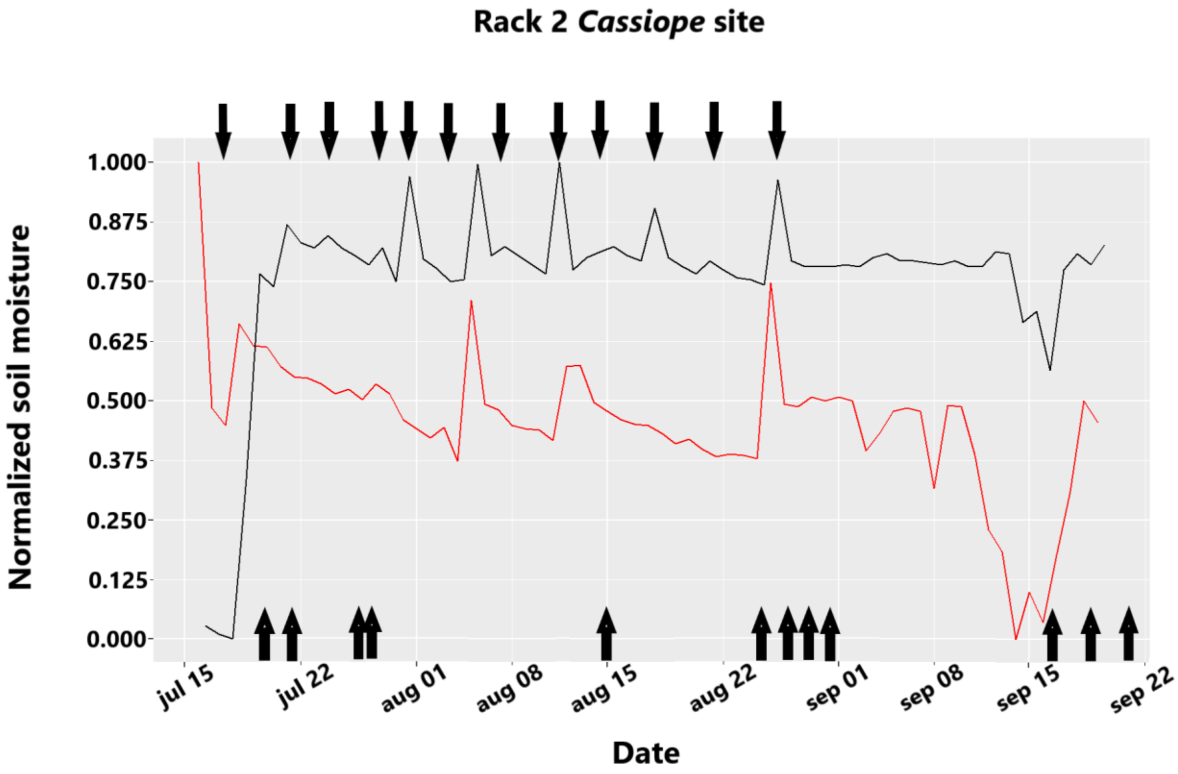

Figure 11: Rack 2, Cassiope site, soil moisture content, Ambient = red line, Watered = black line. Downwards pointing arrows show watering events and upwards pointing arrows show days with substantial natural rainfall (0.3 mm or more).

Figure 11 shows the normalized soil moisture for the *Cassiope* plant community with arrows pointing downwards from the top to indicate the time of experimentally increased soil moisture from watering events. To obtain the normalized values, the normalization formula was used:

$$Xnormalized = \frac{(X - Xmin)}{(Xmax - Xmin)}$$

Arrows pointing upwards from the bottom indicate days of natural rainfall of 0.3 mm or more in the area. From the figure one can see how both experimental watering events and events of natural rainfall affects the soil moisture for this plant community. Normalized values for the soil moisture were chosen to be able to see the peaks of the soil moisture more easily on a normalized scale from 0 – 1. Where the maximum value of the recorded soil moisture for a plot is equal to 1 and the minimum value of the recorded soil moisture for the same plot is equal to 0, and all the other values are a function of itself compared to the max and min values.

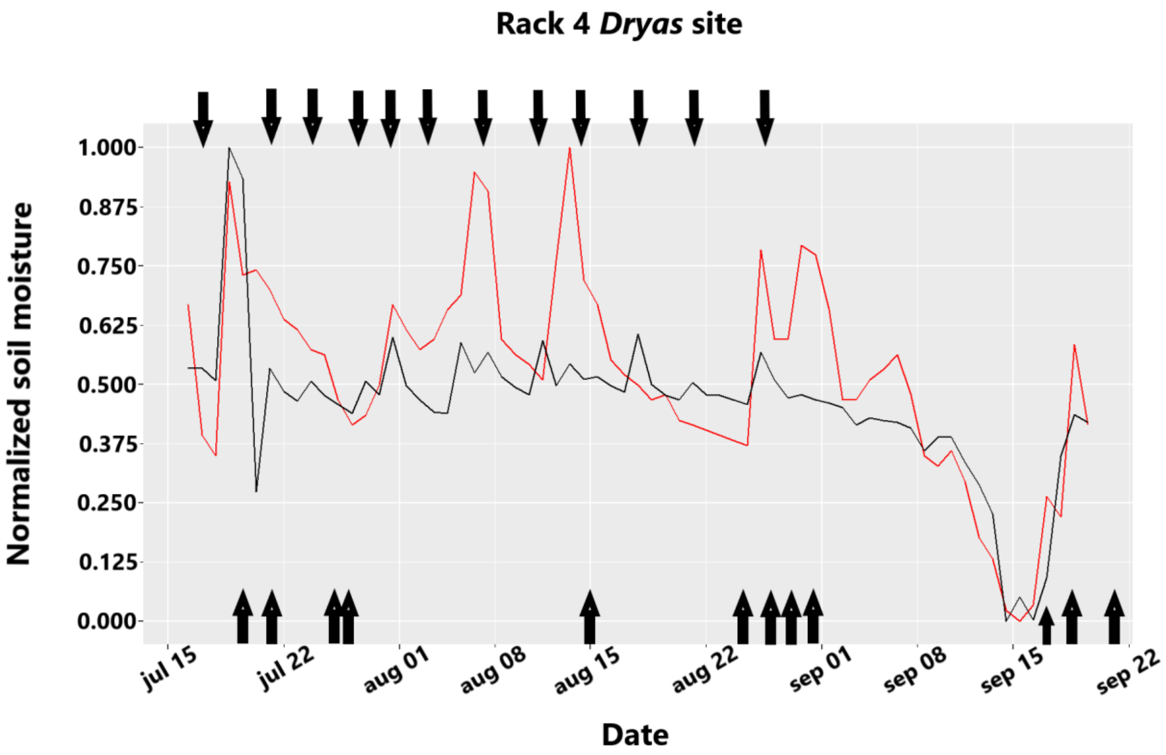

Figure 12: Rack 4, Dryas site, soil moisture content, Ambient = red line, Watered = black line. Downwards pointing arrows show watering events and upwards pointing arrows show days with substantial natural rainfall (0.3 mm or more).

Figure 12 shows the normalized soil moisture for the *Dryas* plant community with arrows pointing downwards from the top to indicate the time of experimentally increased soil moisture from watering events. Arrows pointing upwards from the bottom indicate days of natural rainfall in the area. From the figure one can see how both experimental watering events and events of natural rainfall affects the soil moisture for this plant community.

Table 4: Average soil moisture content for all plots in Rack 2 (Cassiope) and Rack 4 (Dryas).

Rack	Treatment	Soil moisture average
2	Ambient	23
	Watered	23
4	Ambient	8
	Watered	15

All data shown in figures 11 and 12 were collected by the soil moisture sensor (5TM) from Decagon Devices Inc. Figure 11 and Figure 12 shows the change in soil moisture content for the duration of the project, the ambient plot in comparison to the watered plot for Rack 2, *Cassiope* site and Rack 4, *Dryas* site, respectively. Small peaks in the graph seem to correspond with watering events shown in Table 1. One can see small peaks around the dates of the watering events for both of the watered plots. These peaks seem to disappear after the last watering event, which could indicate that the small peaks are in fact a result of the watering events. There is a sudden drop in soil moisture around 12. September, this could be explained by a lack of precipitation for an extended period of time. There are several days of significant rainfall (0.3 mm or more natural precipitation) after 17. September, which increased soil moisture at the end of the sampling period. For these graphs it's interesting to look at how the black line (watered plot) is different from the red line (ambient plot). The black line showing how the soil moisture of the watered plots reacted to each watering event. The arrows on the graphs represent watering events (downwards pointing) and days with natural rainfall (upwards pointing).

The soil moisture content for Rack 2 ambient and watered plots seem to overlap each other quite a lot, making me think that they are equal. The mean for both is 23%. A Welch t-test was performed in R to compare the mean soil moisture value for Rack 2 ambient and Rack 2 watered. There was not a significant difference in the mean soil moisture value between Rack 2 ambient (M = 0.234) and Rack 2 watered (M = 0.230); t(df) = 1.3071 (131.85), p = 0.1934. The test produced a p-value of more than 0.05, this gives a strong indication that the means for the watered plot and the ambient plot are not statistically unequal to each other. This test assumes normality in the data tested, unless the sample size is big enough (>30) to disregard normal distribution. My datasets are comprised of more than 60 observations and the Welch's t-test rank sum test is thus valid.

Going to Rack 4, there seems to be a clear difference in soil moisture between the ambient plot and watered plot. Just how big the difference is, one gets from looking at the mean of the soil moisture for both plots. For Rack 4 ambient, the mean soil moisture is 0.08 whereas the mean of the soil moisture for Rack 4 watered is 0.15. The mean for the watered plot is almost twice as high as the mean for the ambient plot.

In order to find out if the difference in mean for the watered plot and the ambient plot is statistically significant, a Welch's t-test was chosen for these plots as well. The test produced for Rack 4 ambient (M = 0.080) and Rack 4 watered (M = 0.155); t(df) = 20.978 (81.34), p = 2.2e-16. This highly significant result strongly indicates that the means for the watered and ambient plot are statistically different from each other.

From Table 4 there is a clear difference in soil moisture levels between Rack 2 and Rack 4. The soil moisture values are almost twice as high for Rack 2 as for Rack 4, suggesting that Rack 4 is set in a drier area than Rack 2.

4.2.2 NDVI measurements

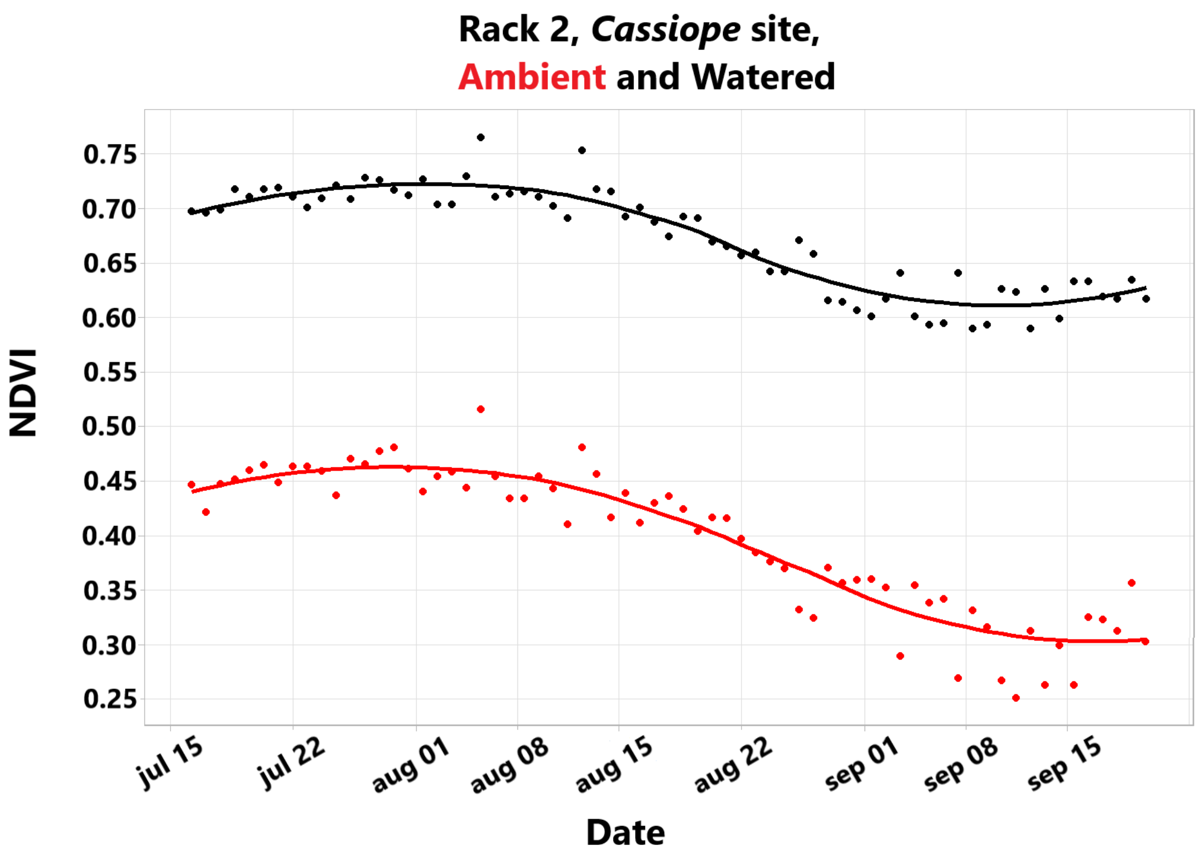

Figure 13: percent change in NDVI for Rack 2, Cassiope site, watered plot = -22.9% and ambient plot = -51.3%

Figure 13 shows the change in NDVI for the *Cassiope* plant community over the sampling period. It shows that the NDVI values for the watered plot are overall higher than the NDVI values for the ambient plot. The percent decline for the NDVI values also show that the NDVI values for the watered plot are more stable and decrease more slowly than the NDVI values for the ambient plot. The difference in NDVI values looks obvious, but if it is statistically significant needs to be analyzed using statistical analysis methods.

Therefore, a Welch t-test was performed in R to compare the mean NDVI value for Rack 2 ambient and Rack 2 watered. There was a significant difference in the mean NDVI values between Rack 2 ambient (M = 0.395) and Rack 2 watered (M = 0.671); t(df) = 27.38 (118.83), p = < 2.2e-16. The t-test produced a p-value of far less than 0.05, this gives a strong indication that the means for the watered plot and the ambient plot are not equal to each other.

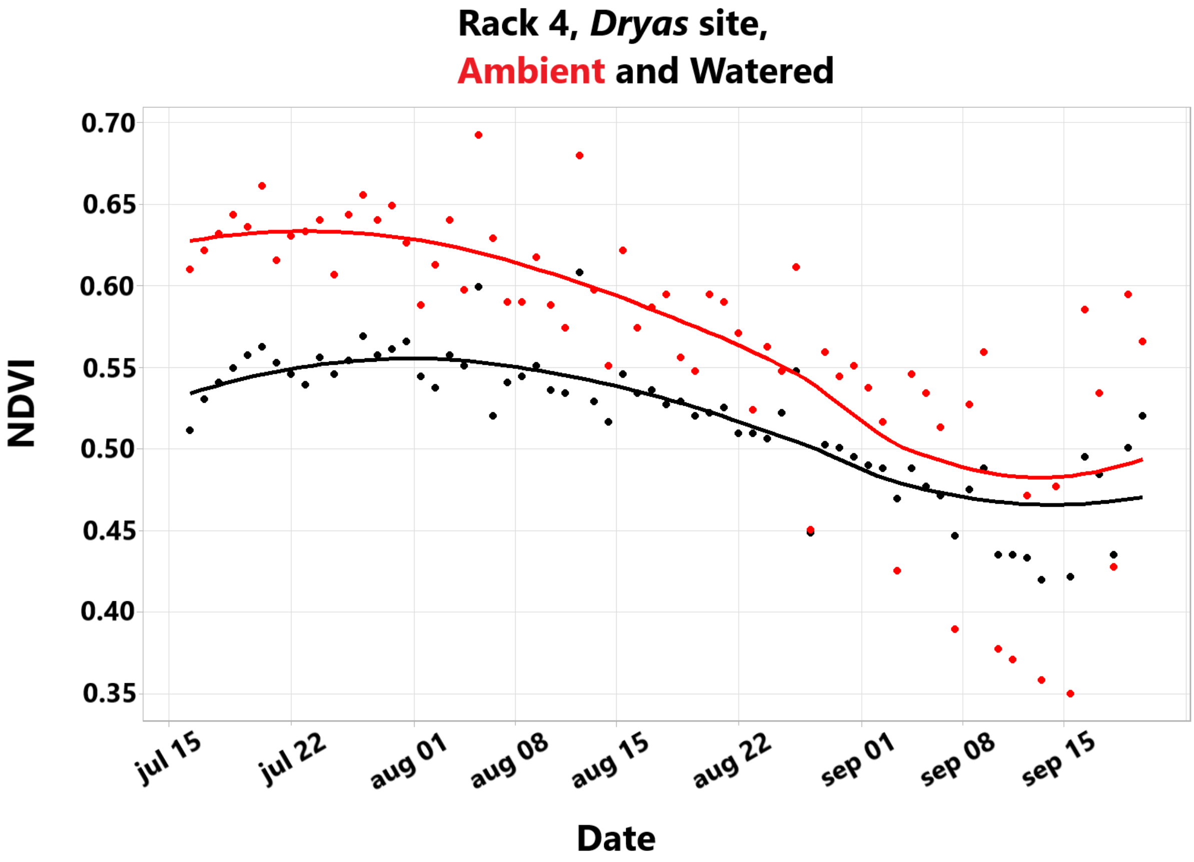

Figure 14: percent change in NDVI for Rack 4, Dryas site, watered plot = - 31.0% and ambient plot = -49.4%

Figure 14 shows the change in NDVI for the *Dryas* plant community over the sampling period. It shows that the NDVI values for the ambient plot are overall higher than the NDVI values for the watered plot. The figure also shows that the NDVI values for the watered plot are more stable than the NDVI values for the ambient plot. This is also proven by the percent decline. The difference in NDVI values looks obvious, but if they are statistically significantly different, they need to be analyzed using statistical analysis methods.

A Welch t-test was performed in R to compare the mean NDVI value for Rack 4 ambient and Rack 4 watered. There was a significant difference in the mean NDVI values between Rack 4 ambient (M = 0. 566) and Rack 4 watered (M = 0. 516); t(df) = 4.558 (100.61), p = 1.456 e^{-05}. The t-test produced a p-value of far less than 0.05, this gives a strong indication that the means for the watered plot and the ambient plot are not equal to each other.

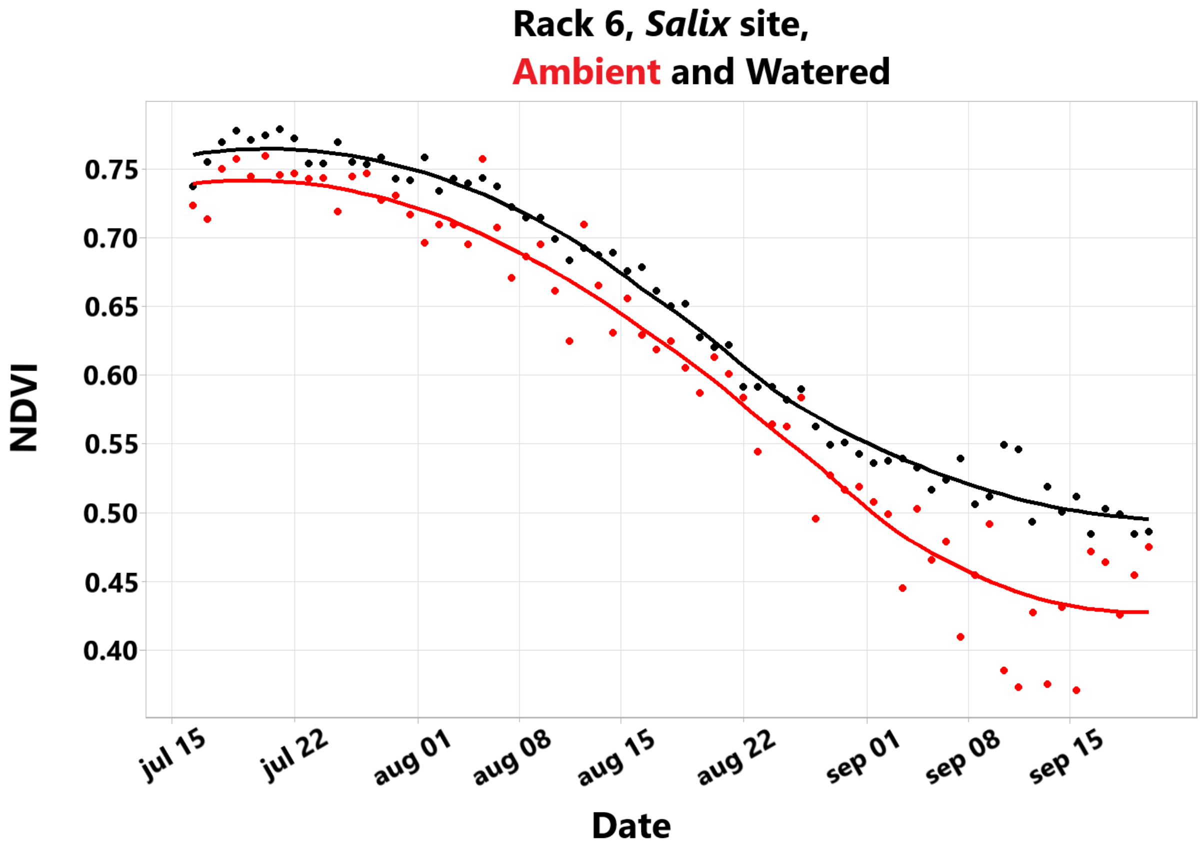

Figure 15: percent change in NDVI for Rack 6, Salix site, watered plot = -37.8% and ambient plot = -51.0%

Figure 15 shows the change in NDVI for the *Salix* plant community over the sampling period. It shows that the NDVI values for the watered plot are overall higher than the NDVI values for the ambient plot. The figure also show that it seems like the NDVI values for the watered plot seem to be more stable, which is proven by the percent decline. The difference in NDVI values looks obvious in the figure, but if it is statistically significant needs to be analyzed using statistical analysis methods.

That is why a Welch t-test was performed in R to compare the mean NDVI value for Rack 6 ambient and Rack 6 watered. There was a significant difference in the mean NDVI values between Rack 6 ambient (M = 0.599) and Rack 6 watered (M = 0.640); t(df) = 2.0755 (128.08), p = 0.03994. The t-test produced a p-value of less than 0.05, this gives an indication that the means for the watered plot and the ambient plot is not equal to each other.

Table 5: percent change in NDVI values for all plots over the course of the experiment.

Rack	Treatment	NDVI % change
2	Ambient	-51.3%
	Watered	-22.9%
4	Ambient	-49.4%
	Watered	-31.0%
6	Ambient	-51.0%
	Watered	-37.8%

The percent change is greater for the ambient plots for all sites than the watered plots, this is true for all racks. (Max and min values for NDVI was used). Even if the NDVI values might be higher for the ambient plot for Rack 4 than the watered plot for Rack 4, the percent decline is greater for the ambient plot than for the watered plot. This indicates that an increase in rainfall leads to more stable NDVI values throughout the growing season. More stable NDVI values indicate more stable production rates for the plants in the studied sites. The Max and Min NDVI values were extracted using the max() and min() function in R Studio after checking that there were no outliers.

The % change is calculated using this equation: $\frac{Min-Max}{Max} \times 100\%$

Max = maximum NDVI value in the dataset

Min = minimum NDVI value in the dataset

For all the sites the peak of the curve for NDVI is located around August 6, except from Rack 6. Here the peak of the curve for NDVI occurred before 6. August, at some point around 22. July.

Figures 13 – 15 shows the NDVI measurements for each rack throughout the project. Rack 2 shows NDVI values that seem to differ from another, with the watered plot having NDVI values higher than the ambient plot. For Rack 4 it looks like the NDVI values for the ambient plot is higher than for the watered plot. The watered plot for Rack 6 looks like it is quite similar to the ambient plot.

The graphs placement within the coordinate systems shows the height of the curve relative to each other. These shows that the NDVI values for Rack 6 are quite a bit higher than the NDVI values for Rack 2 and Rack 4. The plotted NDVI measurements also seem to have less of a spread for the watered plots in contrast to the ambient plots. Leading me to think that additional watering might actually give a more stable production rate for the plants during the growing season. The greenness seems to stay more consistent for additional watering. Although the NDVI values are not directly correlated to productivity of the plant community, they serve as a good relative approximation.

The peak of the curve estimates the peak of the growing season for each plot. The measurements after the peak are all measurements of senescence. Directly after the peak is the start of senescence. This gives us an idea of whether or not and to what degree added water affects the length of the growing season. Just by looking at the curves for Rack 2 it looks like additional water prolongs the growing season.

According to the different plant communities one can see how the plants senesces. The curves for Rack 2 and Rack 6 show a clear decline as *Cassiope* and *Salix* near the end of its growing period. The curves for Rack 4, on the other hand, have much less of a descending curve towards the end of the growing period, this is because *Dryas* is an evergreen shrub and show less of a clear color change during senescence.

4.2.3 Normalized NDVI

Normalized NDVI values gives a clearer relative picture of how the NDVI values changed during the studied period. The normalization of the NDVI values reinforces the variances in NDVI throughout the studied period, with values relative to the max and min value of the ambient plot and the values relative to the max and min value of the watered plot. This makes the NDVI values for the ambient plots sometimes seem higher than those for the watered plots, when in fact the NDVI values for the watered plots are overall higher than the NDVI values for the ambient plots. The normalized NDVI values also make it clearer the actual peak of the growing season, by making the max value of NDVI equal to 1.

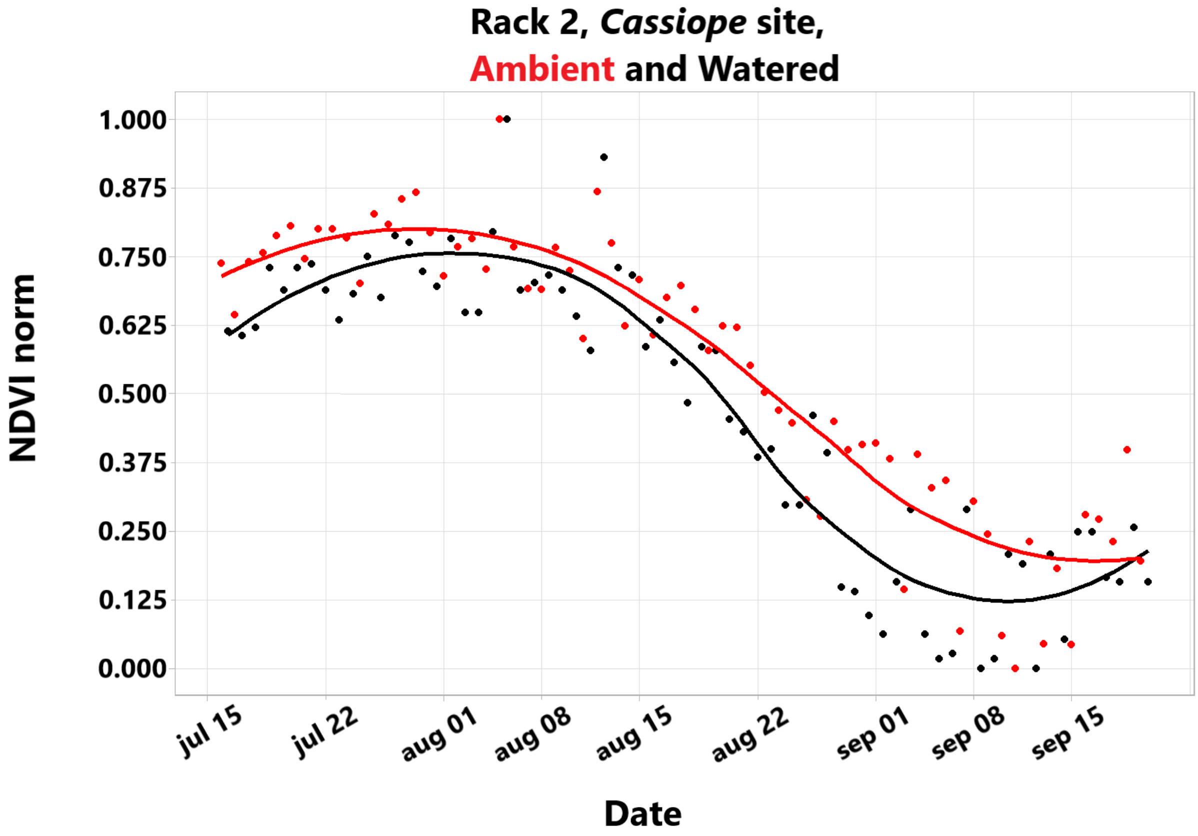

Figure 16: Normalized NDVI values for Rack 2, Cassiope, ambient treatment and watered treatment.

Figure 16 shows the normalized NDVI for the *Cassiope* plant community. It shows that the watered plot and the ambient plot NDVI values change though the sampling period. The ambient plot NDVI values are higher than the NDVI values for the watered plot, but the watered plot gets an increase in NDVI values towards the end of the growing season, unlike the ambient plot, which decreases slightly. With normalized NDVI values it is easier to see the difference in the trend for the NDVI values than for the raw NDVI data. With this graph one can see that the peak of the growing period, and the onset of senescence appears a little later for the watered plot than for the ambient plot. For the ambient and the watered plot, the peak in NDVI values happened at the same date, 5. August.

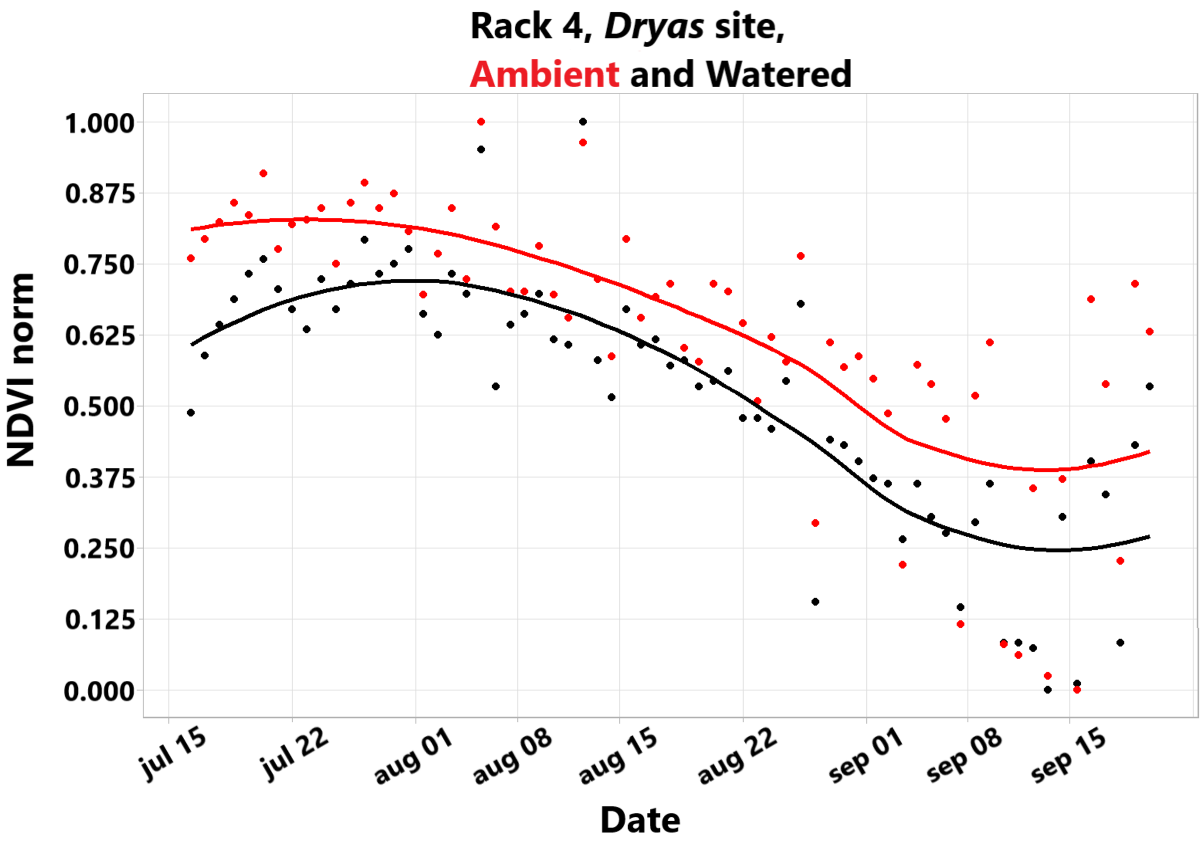

Figure 17: Normalized NDVI values for Rack 4, Dryas, ambient treatment a watered treatment.

Figure 17 shows the normalized NDVI for the *Dryas* plant community. It shows that the watered plot and the ambient plot start out quite differently, the NDVI values for the ambient plot start out higher than the NDVI values for the watered plot. The NDVI values show that the peak of the growing season for the watered plot is a bit later than the peak of the growing season for the ambient plot, which makes the onset of senescence start out later for the watered plot than for the ambient plot. For this plant community the peak of the NDVI values for the ambient plot and the watered plot differed by 7 days, the peak for the ambient plot happened at 5. August and the peak for the watered plot happened at 12. August.

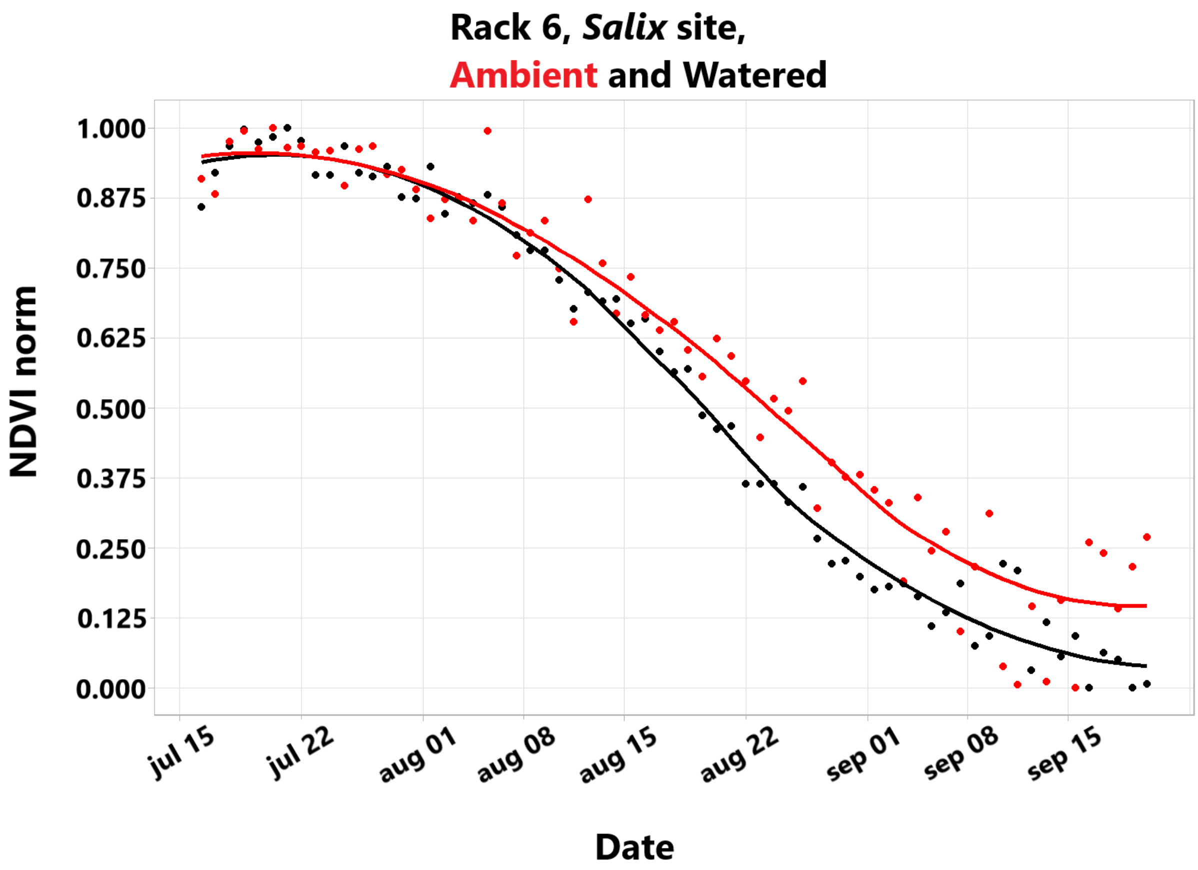

Figure 18: Normalized NDVI values for Rack 6, Salix, ambient treatment and watered treatment.

Figure 18 shows the normalized NDVI values for the *Salix* plant community. It shows that the watered plot and the ambient plot start out quite similarly, but that the watered plot NDVI values decreases more rapidly than the NDVI values for the ambient plot. The same is true for the *Salix* site as for the *Cassiope* site and the *Dryas* site, the peak of the growing season appears to come later for the watered plot than for the ambient plot, which makes the onset of senescence later for the watered plot compared to the ambient plot. The peak of the NDVI values for the ambient and watered plot, happened on 21. July and 22. July, respectively, making the delay in peak NDVI 1 day.

Figures 16 – 18 show the change in the normalized NDVI values for all racks. Normalization was obtained using the normalization formula: $NDVInorm \ = \frac{(n-min)}{(max-min)}$.

The normalized NDVI values give curves with a clearer descend than the non-normalized NDVI values.

4.2.4 Difference in NDVI between ambient and watered plots

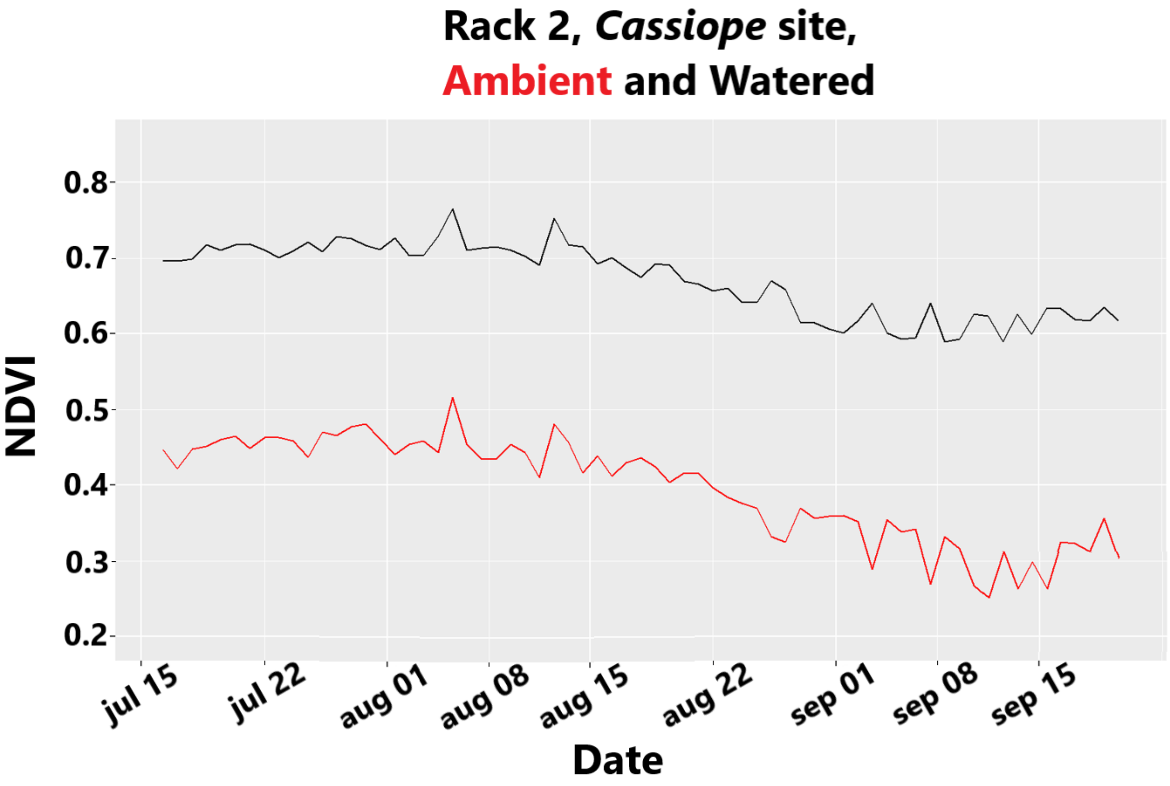

Figure 19: NDVI for the ambient (Red) and watered (Black) plots of Rack 2, Cassiope site, during the sampling period at 12.00 o'clock

Figure 19 shows the NDVI measurements for the *Cassiope* plant community, for both the ambient and watered treatments. The figure shows that the NDVI values for the watered plot in this plant community are higher than for the ambient plot. The NDVI values for the plant community increase over the summer and start to decrease after peaking in the beginning of August. The start of the decrease in NDVI signals the beginning of plant senescence for the community.

After 22. August, one can see small dips in the graph for the NDVI measurements of the ambient plot. This could indicate slight drought stress for the plant community. Inspecting the RGB photos, shows that there were some days with fog during the time of the NDVI-measurements. Something that could possibly affect the sensors' ability to compile reliable measurements. Coinciding with the dips for the ambient plot, there seems to be small peaks for the watered plot in the NDVI measurements after 22. August. Looking at the soil moisture measurements from 4.2.1, the soil moisture for the same period seem to hold steadier for the watered plot, than for the ambient plot. This leads me to believe that, for the *Cassiope* plant community, drought stress is more likely the culprit for the sudden dips in the NDVI measurements for the ambient plot after 22. August.

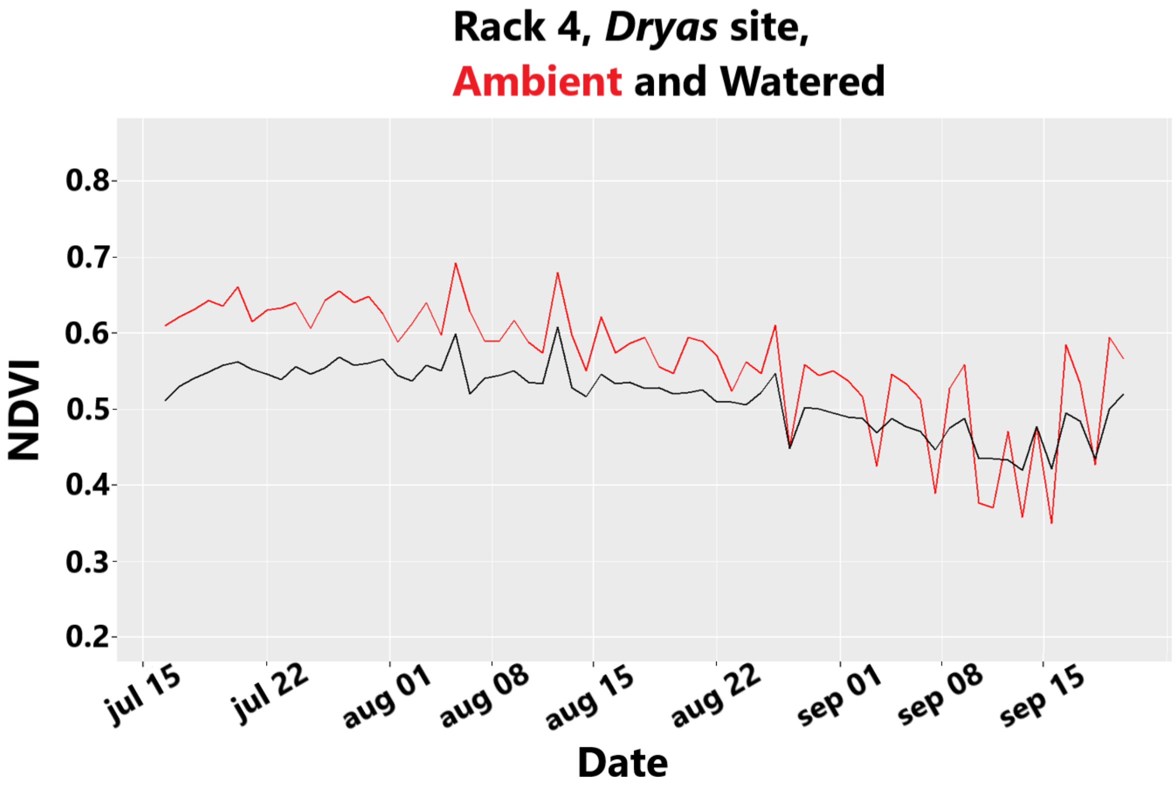

Figure 20: NDVI for the ambient (Red) and watered (Black) plots of Rack 4, Dryas site, during the sampling period at 12.00 o'clock.

Figure 20 shows the NDVI measurements for the *Dryas* plant community, for both the ambient and watered treatments. The figure shows that the NDVI values for the ambient plot in this plant community are slightly higher than for the watered plot. The NDVI values for the plant community increase over the summer and start to decrease after peaking in the beginning of August. The start of the decrease in NDVI signals the beginning of plant senescence for the community. The NDVI values for the watered plot seem to be holding more stable than the NDVI values for the ambient plot.

For the *Dryas* plant community one can also see that there appear sudden dips in the NDVI measurements after 22. August. This time for both the ambient plot and the watered plot. The NDVI measurements for these plots also seem to become more erratic and varying a lot more towards the end of the growing season, compared to the *Cassiope* plant community (Rack 2). Looking at the soil moisture content from 4.2.1 the soil moisture varies quite a lot, especially for the ambient plot, which looks to have a higher soil moisture content, for a period, than the watered plot at this site. This could directly affect the NDVI measurements, as the wet plants interact more with the NIR and red-light spectrum, giving the erratic readings towards the end of the growing period.

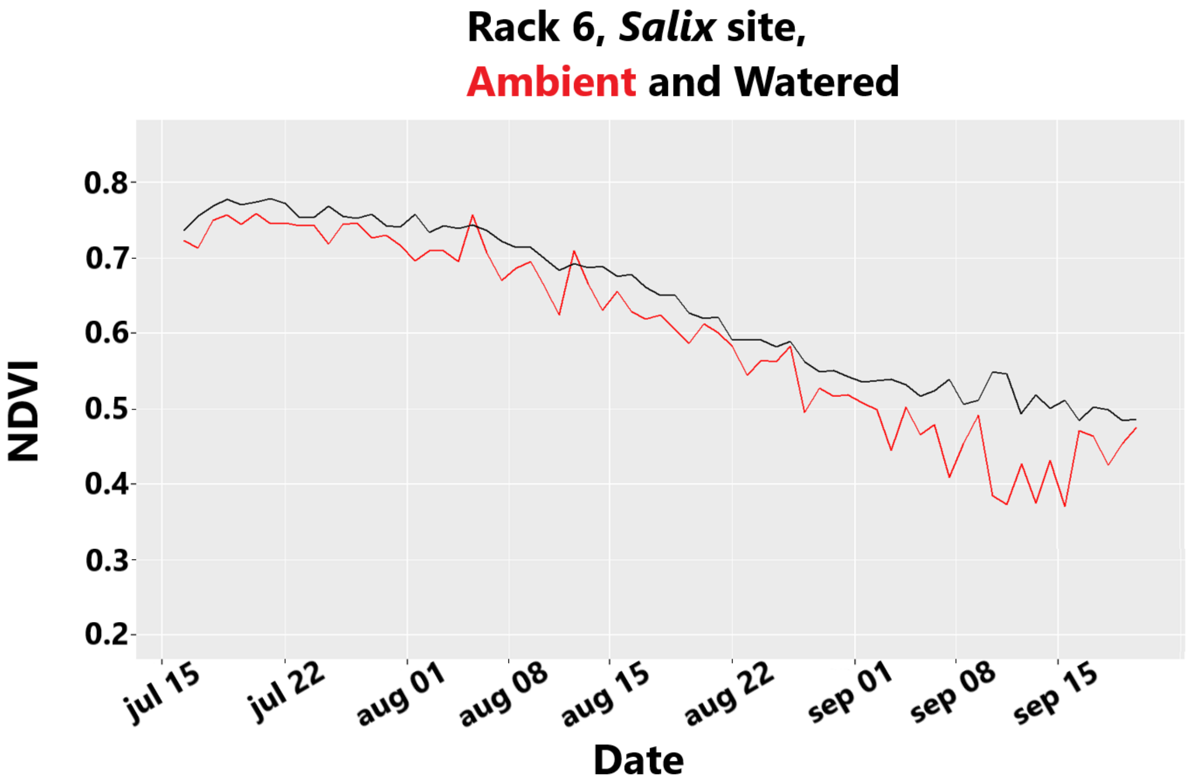

Figure 21: NDVI for the ambient (Red) and watered (Black) plots for Rack 6, Salix site, during the sampling period at 12.00 o'clock.

Figure 21 shows the NDVI measurements for the *Salix* plant community, for both the ambient and watered treatments. The figure shows that the NDVI values for the watered plot in this plant community are slightly higher than for the ambient plot. The NDVI values for the plant community increase over the summer and start to decrease after peaking in the beginning of August. The start of the decrease in NDVI signals the beginning of plant senescence for the community. The NDVI values for the watered plot seem to be more stable through the entire sampling period than for the NDVI values for the ambient plot.

For the *Salix* plant community, the soil moisture and temperature sensors failed to record any data. This makes the task of analyzing and interpreting the NDVI data more difficult. Knowing that the soil is composed of fine grain sand, and that the watered plot received the additional water treatment, one can assume that the soil moisture for the watered plot is somewhat higher than the soil moisture for the ambient plot. This could be the reason that the NDVI values through the growing period looks to hold steadier for the watered plot, than for the ambient plot. Especially looking at the period after 22. August, towards the end of the growing period, the NDVI measurements for the ambient plot seem to vary quite a lot more than the NDVI measurements for the watered plot.

Comparing the NDVI measurements to the soil moisture content for the same plot, one can see how the addition of water affects the NDVI readings for each plant community. The NDVI is in this context used as a proxy for plant community productivity. There is no direct relationship between NDVI levels and plant productivity but could be used to compare productivity relatively. There seems to be a difference in the level of the NDVI values and development over the sampling period between the watered plot and the ambient plot for all racks.

4.2.5 Soil moisture and NDVI

The relationship between NDVI and soil moisture for the ambient plot and watered plot for Rack 2 and Rack 4 is shown in Figures 22 and 23.

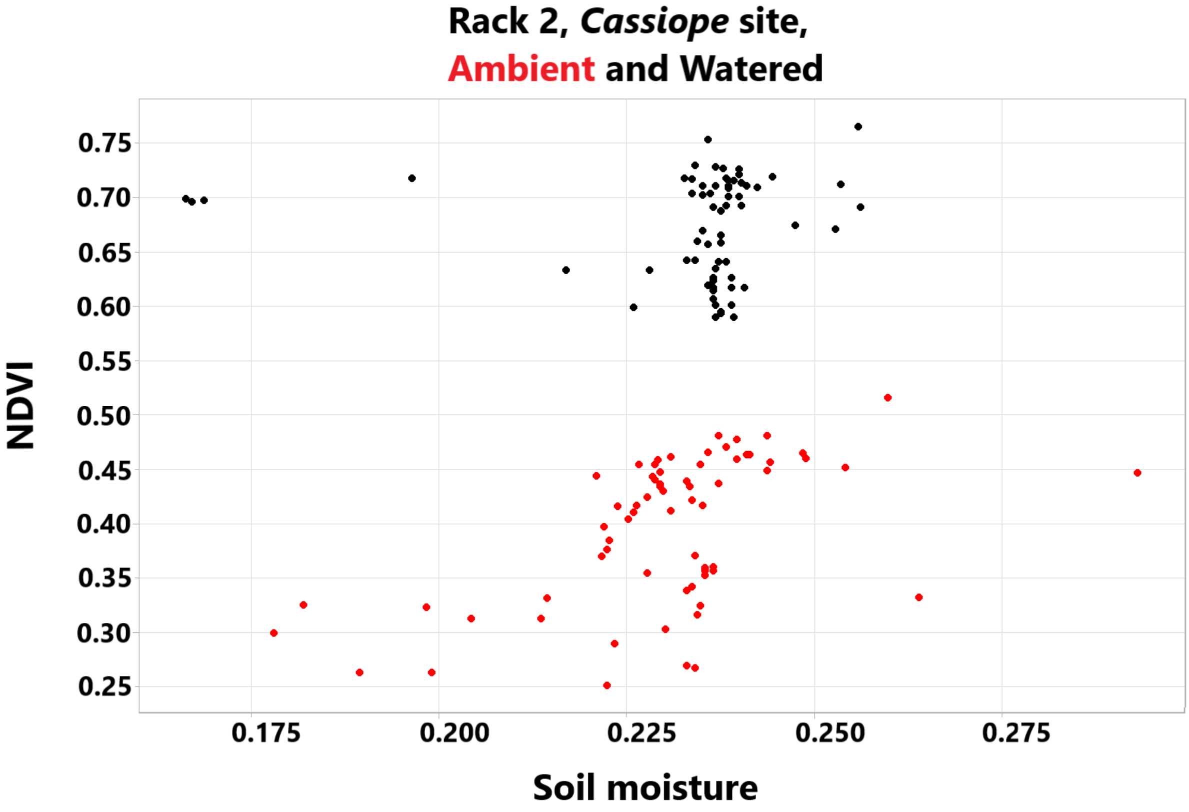

Figure 22: NDVI plotted against soil moisture for rack 2, Cassiope site, ambient and watered plots.

Figure 22 shows the relationship between NDVI and soil moisture for the *Cassiope* plant community, both for the ambient and the watered plot. The figure show that the NDVI for the watered plot is higher than the NDVI for the ambient plot, even if they show similar soil moisture content from the sensor.

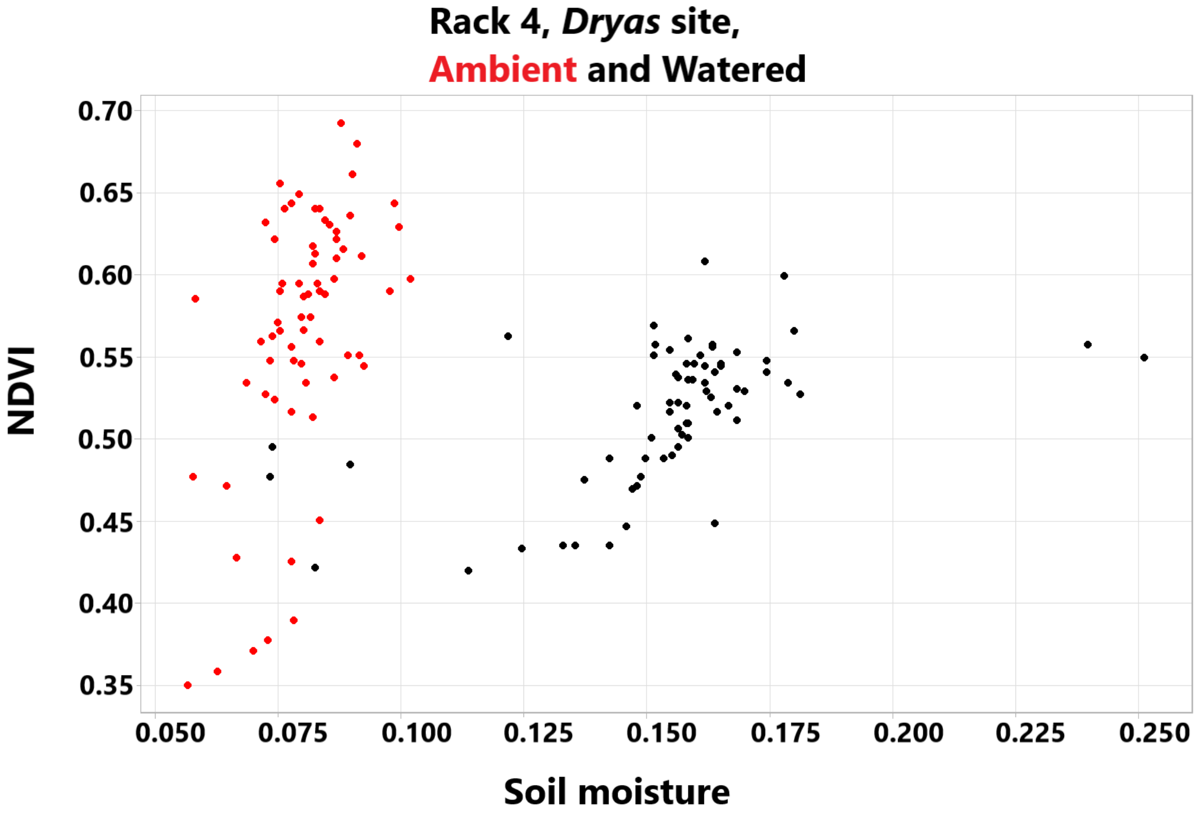

Figure 23: NDVI plotted against soil moisture for Rack 4, Dryas site, ambient and watered plots.

Figure 23 shows the relationship between NDVI and soil moisture for the *Dryas* plant community, for both the watered and ambient plot. The figure shows that the NDVI values for the ambient plot is, overall higher for the ambient plot than for the watered plot, though the soil moisture for the watered plot is higher and more variable than for the ambient plot.

Table 6: Correlation between soil moisture and NDVI for all plots in Rack 2 (Cassiope) and Rack 4 (Dryas).

Rack	Treatment	NDVI and soil moisture Spearman's correlation
2	Ambient	0.56
	Watered	0.13
4	Ambient	0.51
	Watered	0.59

Figures 22 and 23 shows that there could be a correlation between soil moisture and NDVI values. To test this a Spearman's correlation test was performed for the soil moisture to NDVI values, this test was chosen over Pearson's because the data does not seem to follow a straight trend line, but rather a curved trend line. For Rack 2 watered Spearman's rho = 0.13, indicating that there is a weak positive correlation between the soil moisture and NDVI values for the watered plot for Rack 2. For the ambient plot, the same test was done, the test gift a Spearman's rho = 0.56, indicating a positive correlation between the soil moisture and NDVI values for the ambient plot for Rack 2.

For Rack 4 the Spearman's rho for the watered plot = 0.59, and for the ambient plot the Spearman's rho = 0.51. Both rho values for this rack show a better positive correlation between the soil moisture and NDVI values for the watered plot in Rack 2.

4.2.6 Soil temperature

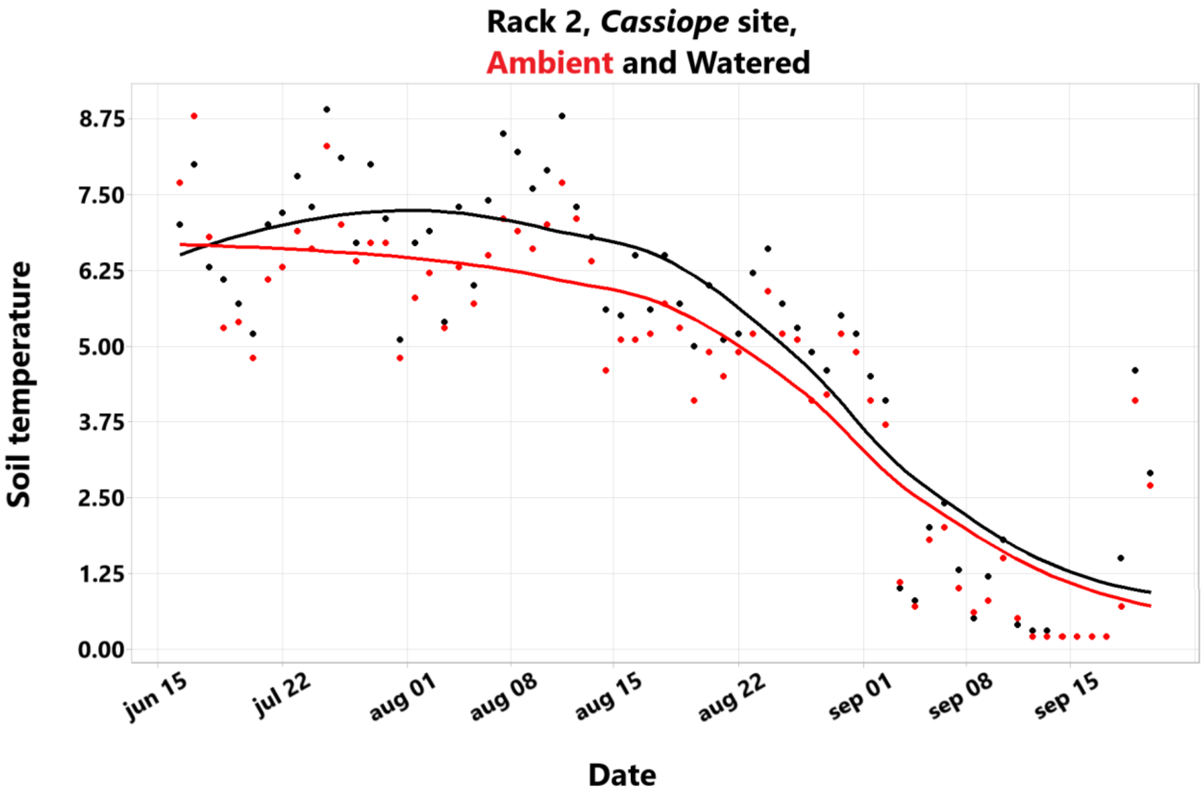

Figure 24: Soil temperature with trendlines for Rack 2 Ambient and Watered plots. Soil temperature in degrees Celsius.

Figure 24 shows the trend of the temperature of the soil for the *Cassiope* plant community for the summer of 2021. The soil temperature of the watered plot is colored black and the soil temperature for the ambient plot is colored red. As seen from figure 20, the soil temperature for the watered plot is slightly higher than the soil temperature for the ambient plot. The temperature in the soil increases though the summer and starts to decrease in late July, early August.

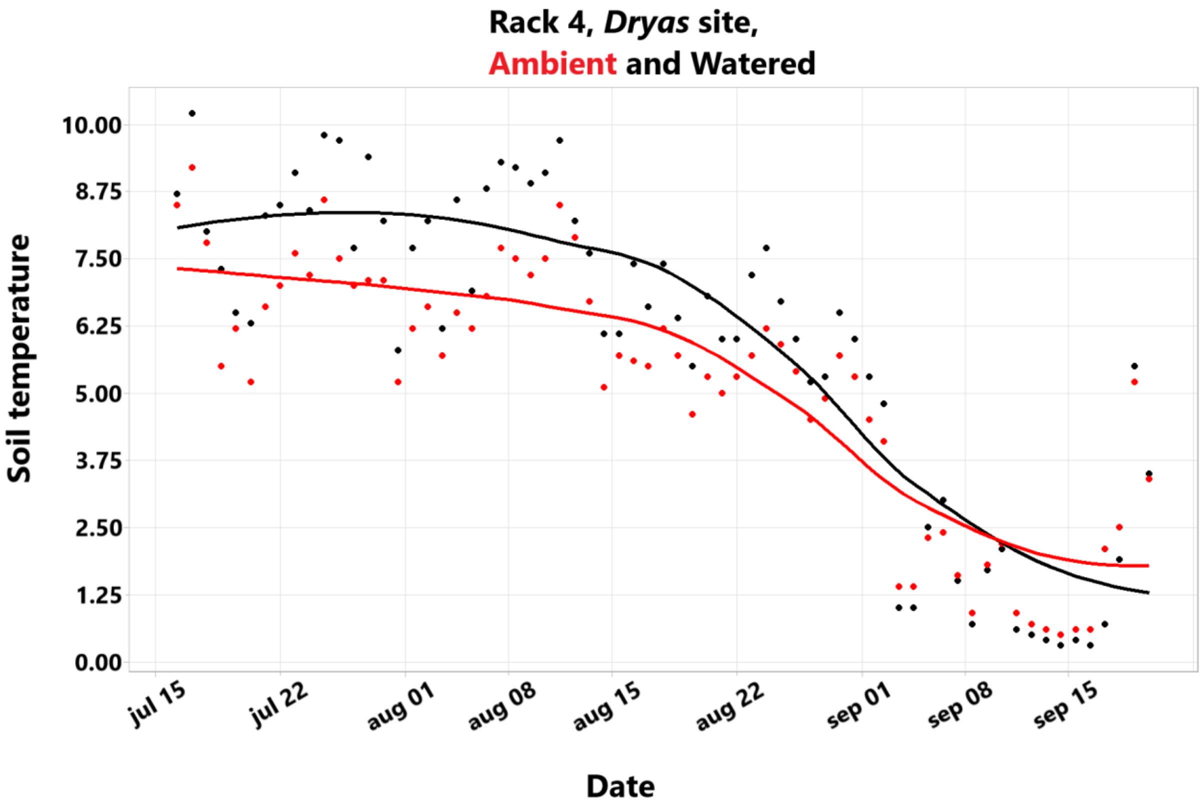

Figure 25: Soil temperature with trendlines for Rack 4 Ambient and Watered plots. Soil temperature in degrees Celsius.

Figure 25 shows the soil temperature through the summer of 2021 in the *Dryas* plant community. The same trend is observed for the *Dryas* plant community as for the *Cassiope* plant community shown in figure 23. Temperatures increase through the summer and start to decrease in late July to early August.

5 Discussion:

There have been many studies on the phenology of plants, mostly on how snow cover duration and quality affects spring phenology. There have been quite few studies on how NDVI and autumn phenology are affected by soil moisture content during the main growing period in high Arctic areas. In order to better understand how the productivity of plant communities will be affected by climate change, more studies on how an increase in precipitation and temperature affects the plant phenology for the entire growing season, including especially the end of the growing period.

5.1 Soil moisture and soil composition

Keuper et al. (2012) chose in their study in Siberia and Sweden to increase the experimental precipitation by 100%. Christiansen et al. (2012) increased precipitation to roughly twice the natural precipitation in NE Greenland during their 2009 study. While Sharp et al. (2013) chose to increase the summer precipitation by 5 mm weekly through June and August and 10 mm weekly through July to their 2009 experiment in NW Greenland. Baddeley et al. (1994) ran an experiment with the addition of nutrition on Svalbard, where they chose to run control plots with and without additional watering. They found no significant difference between the watered and unwatered control plots. They chose to add 2 mm of precipitation to the watered control plot, which is substantially less water added for that experiment, compared to the addition of water in this experiment.

The difference in vegetation composition has an effect on the NDVI values, the amount and size of the flowers as well as the shade of green and amount of living plant material affects the amount of green and near infrared light emitted from the ground. But in this case, the interest is found in looking at the change in NDVI over time compared to plots with similar vegetation composition, watered to ambient for each rack. This is in line with what Engstrom et al. (2008) found in Alaska in their study of whether or not there is a significant relationship between soil moisture and NDVI. They reported that in areas with good drainage, plants have less access to water and that an increase in soil moisture in these areas will have a significant relationship with the NDVI measurements.

The texture of the soil differs slightly from plant community to plant community in this study. For the *Cassiope* plant community the soil texture is quite coarse with pebbles and stone, providing good drainage. For the *Dryas* plant community, the soil is a mixture of coarse materials and fine sand, providing good drainage with some retention of moisture in between the veneer sand particles. For the *Salix* plant community, the soil is composed of fine sand and provides less drainage than for the previous plant communities, this makes our results of greater difference in the change of NDVI for the *Cassiope* site and least change in the *Dryas* site, coincide with the findings of Engstrom et al. (2008). The difference in soil composition, abundance of bryophytes and root length of the plants in each plant community determines how much of the added water and natural rainfall actually reaches the soil moisture sensor, and in turn how the data of the soil moisture is presented.

The results show that an increase in water content does influence vegetation productivity in this area. The watered plots had an overall higher NDVI mean value than the ambient plots. They stayed greener for longer and had more consistent NDVI values throughout the end of the growing season. The percent change in NDVI proves that the plots with additional water had more consistent NDVI values throughout the growing season. Liu, et al. (2016) found similar results of NDVI trends. NDVI is considered to be a good way of assessing vegetation productivity, and it does change in this experiment in contrast to the controls for the project. This indicates that an increase in soil moisture causes an increase in plant community productivity, as found by Gamon, et al. (1995) for the studied sites. Opala-Owczarek, et al., (2018) found in their study on Svalbard, that soil moisture from summer precipitation had significant influence on growth ring width of *S. polaris*.

5.2 Soil moisture and NDVI

The plots for Rack 4 report of lower soil moisture than the plots for Rack 2. According to the hypothesis, the plots for Rack 2 should by that account have higher values for NDVI than the plots for Rack 4. My data shows that the mean NDVI values are in fact higher for Rack 2 than for Rack 4. This is likely due to plant community composition, rather than to soil moisture content alone. The plots at Rack 2 have an overall higher amount of living plant material than the plots at Rack 4. This means that the plant community at Rack 2 will have a bigger influence on the NDVI measurements. The location of the soil moisture sensor could have a significant influence on the measured soil moisture for an experiment like this. The soil moisture sensor in this experiment was set 10 cm below ground. The roots of most of the plants in this study do not reach as low as 10 cm, as indicated in an unpublished study project by D’Imperio et al. (Unpublished) in Adventdalen in 2015. This means that the roots of the plants might have absorbed the excess water from the watering events before the water could reach the soil moisture sensor. The depth of the plant roots should be considered when placing a soil moisture sensor. One can with advantage place several soil moisture sensors in each plot, at several depths and locations. This could aid in seeing how proficient the plant community is to utilize the added water, and at what depth does the plants in the plot absorb all the added water.

5.3 Plant community

The presence of bryophytes in the plots could possibly lead to a skewed interpretation of NDVI values as May et al., (2018) found in their study on NDVI of moss communities.

Bryophytes are found in each of the plots for this experiment, although the vascular plants are in abundance compared to the bryophytes, the bryophytes stand to make a considerable contribution to the response in NDVI after a watering event. The main bryophyte species in the area is *S. uncinata*. Which is a green moss that could definitively contribute to the NDVI readings.

The project was conducted in Adventdalen, where there are among other wild Svalbard reindeer, birds, Arctic foxes and polar bears. All animals have complete access to the sites and the reindeer graze all over Adventdalen during summer. The NDVI sensors and RGB cameras take measurements and pictures at their preset times no matter whether or not there are animals in the plots. This could cause significant errors in individual NDVI measurements. *Dryas octopetala* is a species that blooms in big white flowers, this means that an abundance in *D. octopetala* might affect NDVI measurements.

5.4 Soil temperature and productivity

Soil temperature is one of the most important factors for plant growth and productivity. In this study the soil temperature for the *Cassiope* and *Dryas* plant communities were recorded. The soil temperatures show similar trends for both plant communities. The soil temperatures increase during the summer and the temperature starts to decline towards the end of July and the beginning of August. The soil temperatures coincide with the local air temperature. This study did not experimentally alter the temperature of any of the plots. In future studies, a combination of increased precipitation and increased temperatures should be studied as the forecasted climate change for the area includes both.

Several studies in the past found that an elevation in soil temperature might reduce NDVI measurements, due to increased transpiration decreasing the soil moisture (Oberbauer et. al. (2013), Mayers-Smith et. al. (2019), Gehrman et. al. (2021)). The drought stress brought on by increased temperatures, with no increase in precipitation, could lead to earlier onset of senescence (Chen et. al. (2020)).

5.5 Equipment malfunction

Even if some of the equipment for the *Salix* plant community failed, it is clear that the watered plot was treated with additional water compared to the ambient plot. Although there is no possibility to look at the NDVI values compared to the soil moisture, but there is still the possibility to look at the changes in NDVI values and compare those values for the watered and ambient plots. For the *Salix* plant community site, the NDVI values show an increase for the watered plot, compared to the ambient plot. This indicates that the added water to the watered plot did have an effect on the productivity of the *Salix* plant community. These findings correlate with what Liu, et al., (2016) found in their study on how NDVI values in arid and semi-arid regions respond to an increase in precipitation. To avoid problems like this in the future one might consider doing extra spot measurements in situ with a handheld soil moisture meter, a while after the watering events.

This study indicates that an increase in precipitation might increase plant community productivity by elongating the growing period by slowing down the rate of senescence. An increase in summer precipitation might also increase the depth of thaw of permafrost in the area as found by Grant et al., (2019). According to Lupascu, et al., (2014) this could possibly release the massive carbon storage that the tundra is.

The results of a longer growing period could bring significant benefits to plants that could grow for a significant amount of time after others. They would be able to stock up on nutrients before the winter, giving them a greater advantage in the following spring. At the same time, an elongation of the growing period could also be of great disadvantage if the winter comes suddenly, before the plants have finished senescence. Giving frost damage to fragile parts of the plant.

6 Conclusion:

We have studied three different plant communities, dominated by *C. tetragona*, *D. octopetala* and *S. polaris*, respectively, that are commonly distributed in the High Arctic. The purpose of this study was to analyze how these plant communities might respond to some of the factors brought on by climate change.

For this reason, an experimental setup was established, increasing the availability of water content to plants during the growing season. The data shows that an increase in soil moisture does have an effect on plant community productivity towards the end of the growing season. The magnitude of decrease in NDVI values was less in the watered plots compared to the ambient plots. That is, it shows that the onset of senescence is delayed by an addition of water. The study also reinforces findings from previous studies that an addition of water during the growing period does have an effect on the onset and duration of senescence, and that the magnitude of the response is species specific as well as dependent on physical soil properties.

The change in NDVI was decreased by an average of 20% by adding a total of 90 mm extra water during the growing period. The plant community with the highest response, of 28.4 % less change in NDVI values, was the *Cassiope* plant community, the plant community with the least change in NDVI was the *Salix* plant community, with 13.2% difference in NDVI change between the ambient and watered plots. The average difference in delayed onset of senescence was 2.6 days, with the *Cassiope* plant community showing no delay in onset of senescence, the *Dryas* plant community had a delay in onset of senescence of 7 days and the *Salix* plant community had a delay in onset of senescence of 1 day. The physical properties of the soil, whether the soil is composed of pebbles (coarse) or fine sand, determines how well the added water is retarded, and therefore how much time the roots of the plant has to absorb the water, and how well the plant get to utilize the addition of water.

During the process of completing this experiment and thesis, I have learned so many things that I will take with me into my new career as a natural sciences and biology teacher. I learned how to complete a research study from start to finish, to reflect over findings and possible explanations as to why some things happen as they do, try your best to always prepare for just about anything. I learned some simple programming, which is very important considering the new teaching methods newly implemented by the government includes programming as part of teaching and learning for all grades in all classes in the Norwegian public school system. All in all, I think of this experience as character building and great preparation for the future.

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9 Appendix

9.1 A – Percent cover data

9.1.1 Rack 2, *Cassiope* site

Species	Rack 2 Ambient Live %	Rack 2 Ambient Dead %	Rack 2 Watered Live %	Rack 2 Watered Dead %
Cassiope	5	1	23	2
Dryas	49	5	28	2
Salix	3	0	10	0
Bistorta	2	0	2	0
Pedicularis	1	0	1	0
Alopecurus	0	0	0	0
Luzula	1	2	2	2
Other grasses	0	0	0	0
Other vascular	1	0	3	0
Bryophytes	10	0	12	0
Lichens	6	0	3	0
Soil	9	0	7	0
Stone	5	0	1	0
Droppings	0	0	2	0
Total Cover		100		100

9.1.2 Rack 4, *Dryas* site

Species	Rack 4 Ambient Live %	Rack 4 Ambient Dead %	Rack 4 Watered Live %	Rack 4 Watered Dead %
Cassiope	0	0	0	0
Dryas	20	5	20	7
Salix	10	0	8	0
Bistorta	1	0	1	0
Pedicularis	1	0	0	0
Alopecurus	0	0	0	0
Luzula	1	1	6	4
Other grasses	1	1	0	0
Other vascular	1	0	1	0
Bryophytes	6	0	5	0
Lichens	25	0	24	0
Soil	25	0	23	0
Stone	0	0	0	0
Droppings	2	0	1	0
Total Cover		100		100

9.1.3 Rack 6, *Salix* site

Species	Rack 6 Ambient Live %	Rack 6 Ambient Dead %	Rack 6 Watered Live %	Rack 6 Watered Dead %
Cassiope	0	0	0	0
Dryas	1	0	1	0
Salix	76	0	61	4
Bistorta	1	0	2	0
Pedicularis	1	0	1	0
Alopecurus	3	7	10	15
Luzula	1	0	0	0
Other grasses	1	1	1	1
Other vascular	0	0	0	0
Bryophytes	3	0	1	0
Lichens	1	0	2	0
Soil	4	0	1	0
Stone	0	0	0	0
Droppings	0	0	1	0
Total Cover		100		100

9.2 B – NDVI Data

9.2.1 Rack 2, *Cassiope* site

Date:	Ambient:	Watered:
16.07.2021 12:00	0,447	0,697
17.07.2021 12:00	0,421	0,696
18.07.2021 12:00	0,447	0,698
19.07.2021 12:00	0,452	0,718
20.07.2021 12:00	0,460	0,711
21.07.2021 12:00	0,464	0,718
22.07.2021 12:00	0,449	0,719
23.07.2021 12:00	0,463	0,711
24.07.2021 12:00	0,463	0,701
25.07.2021 12:00	0,459	0,709
26.07.2021 12:00	0,437	0,721
27.07.2021 12:00	0,470	0,708
28.07.2021 12:00	0,465	0,728
29.07.2021 12:00	0,477	0,726
30.07.2021 12:00	0,480	0,716
31.07.2021 12:00	0,461	0,712
01.08.2021 12:00	0,440	0,727
02.08.2021 12:00	0,454	0,703
03.08.2021 12:00	0,458	0,703
04.08.2021 12:00	0,443	0,729
05.08.2021 12:00	0,516	0,765
06.08.2021 12:00	0,454	0,711
07.08.2021 12:00	0,434	0,713
08.08.2021 12:00	0,434	0,715
09.08.2021 12:00	0,454	0,711
10.08.2021 12:00	0,443	0,702
11.08.2021 12:00	0,410	0,691
12.08.2021 12:00	0,481	0,753
13.08.2021 12:00	0,456	0,718
14.08.2021 12:00	0,416	0,715
15.08.2021 12:00	0,439	0,692
16.08.2021 12:00	0,412	0,701
17.08.2021 12:00	0,430	0,687
18.08.2021 12:00	0,436	0,674
19.08.2021 12:00	0,424	0,692
20.08.2021 12:00	0,404	0,691
21.08.2021 12:00	0,416	0,669
22.08.2021 12:00	0,416	0,665
23.08.2021 12:00	0,397	0,657
24.08.2021 12:00	0,384	0,660
25.08.2021 12:00	0,376	0,642
26.08.2021 12:00	0,369	0,642

27.08.2021 12:00	0,332	0,670
28.08.2021 12:00	0,324	0,658
29.08.2021 12:00	0,370	0,616
30.08.2021 12:00	0,356	0,614
31.08.2021 12:00	0,359	0,607
01.09.2021 12:00	0,360	0,601
02.09.2021 12:00	0,352	0,617
03.09.2021 12:00	0,289	0,640
04.09.2021 12:00	0,354	0,601
05.09.2021 12:00	0,338	0,593
06.09.2021 12:00	0,342	0,594
07.09.2021 12:00	0,269	0,640
08.09.2021 12:00	0,332	0,590
09.09.2021 12:00	0,316	0,593
10.09.2021 12:00	0,267	0,626
11.09.2021 12:00	0,251	0,623
12.09.2021 12:00	0,312	0,590
13.09.2021 12:00	0,263	0,626
14.09.2021 12:00	0,299	0,599
15.09.2021 12:00	0,263	0,633
16.09.2021 12:00	0,325	0,633
17.09.2021 12:00	0,323	0,619
18.09.2021 12:00	0,312	0,617
19.09.2021 12:00	0,357	0,635
20.09.2021 12:00	0,303	0,617

9.2.2 Rack 4, *Dryas* site

Date:	Ambient:	Watered:
16.07.2021 12:00	0,610	0,511
17.07.2021 12:00	0,622	0,531
18.07.2021 12:00	0,632	0,541
19.07.2021 12:00	0,643	0,549
20.07.2021 12:00	0,636	0,558
21.07.2021 12:00	0,661	0,563
22.07.2021 12:00	0,616	0,553
23.07.2021 12:00	0,630	0,546
24.07.2021 12:00	0,633	0,539
25.07.2021 12:00	0,640	0,556
26.07.2021 12:00	0,607	0,546
27.07.2021 12:00	0,643	0,554
28.07.2021 12:00	0,656	0,569
29.07.2021 12:00	0,640	0,558
30.07.2021 12:00	0,649	0,561
31.07.2021 12:00	0,626	0,566

01.08.2021 12:00	0,588	0,544
02.08.2021 12:00	0,613	0,537
03.08.2021 12:00	0,640	0,558
04.08.2021 12:00	0,598	0,551
05.08.2021 12:00	0,692	0,599
06.08.2021 12:00	0,629	0,520
07.08.2021 12:00	0,590	0,541
08.08.2021 12:00	0,590	0,544
09.08.2021 12:00	0,617	0,551
10.08.2021 12:00	0,588	0,536
11.08.2021 12:00	0,574	0,534
12.08.2021 12:00	0,680	0,608
13.08.2021 12:00	0,598	0,529
14.08.2021 12:00	0,551	0,517
15.08.2021 12:00	0,622	0,546
16.08.2021 12:00	0,574	0,534
17.08.2021 12:00	0,587	0,536
18.08.2021 12:00	0,594	0,527
19.08.2021 12:00	0,556	0,529
20.08.2021 12:00	0,548	0,520
21.08.2021 12:00	0,594	0,522
22.08.2021 12:00	0,590	0,525
23.08.2021 12:00	0,571	0,510
24.08.2021 12:00	0,524	0,510
25.08.2021 12:00	0,563	0,506
26.08.2021 12:00	0,548	0,522
27.08.2021 12:00	0,611	0,548
28.08.2021 12:00	0,451	0,449
29.08.2021 12:00	0,559	0,502
30.08.2021 12:00	0,544	0,501
31.08.2021 12:00	0,551	0,495
01.09.2021 12:00	0,537	0,490
02.09.2021 12:00	0,517	0,488
03.09.2021 12:00	0,425	0,469
04.09.2021 12:00	0,546	0,488
05.09.2021 12:00	0,534	0,477
06.09.2021 12:00	0,513	0,471
07.09.2021 12:00	0,389	0,447
08.09.2021 12:00	0,527	0,475
09.09.2021 12:00	0,559	0,488
10.09.2021 12:00	0,377	0,435
11.09.2021 12:00	0,371	0,435
12.09.2021 12:00	0,471	0,433
13.09.2021 12:00	0,358	0,419
14.09.2021 12:00	0,477	0,477
15.09.2021 12:00	0,350	0,421

16.09.2021 12:00	0,585	0,495
17.09.2021 12:00	0,534	0,484
18.09.2021 12:00	0,427	0,435
19.09.2021 12:00	0,594	0,501
20.09.2021 12:00	0,566	0,520

9.2.3 Rack 6, *Salix* site

Date:	Ambient:	Watered:
16.07.2021 12:00	0,723	0,737
17.07.2021 12:00	0,713	0,755
18.07.2021 12:00	0,750	0,769
19.07.2021 12:00	0,757	0,778
20.07.2021 12:00	0,744	0,771
21.07.2021 12:00	0,759	0,774
22.07.2021 12:00	0,745	0,779
23.07.2021 12:00	0,747	0,772
24.07.2021 12:00	0,742	0,754
25.07.2021 12:00	0,743	0,754
26.07.2021 12:00	0,719	0,769
27.07.2021 12:00	0,744	0,755
28.07.2021 12:00	0,747	0,753
29.07.2021 12:00	0,727	0,758
30.07.2021 12:00	0,730	0,742
31.07.2021 12:00	0,716	0,741
01.08.2021 12:00	0,696	0,758
02.08.2021 12:00	0,709	0,734
03.08.2021 12:00	0,709	0,742
04.08.2021 12:00	0,695	0,739
05.08.2021 12:00	0,757	0,743
06.08.2021 12:00	0,707	0,737
07.08.2021 12:00	0,670	0,722
08.08.2021 12:00	0,686	0,714
09.08.2021 12:00	0,695	0,714
10.08.2021 12:00	0,661	0,698
11.08.2021 12:00	0,625	0,683
12.08.2021 12:00	0,709	0,692
13.08.2021 12:00	0,665	0,687
14.08.2021 12:00	0,630	0,689
15.08.2021 12:00	0,656	0,676
16.08.2021 12:00	0,629	0,678
17.08.2021 12:00	0,619	0,661
18.08.2021 12:00	0,625	0,650
19.08.2021 12:00	0,605	0,652
20.08.2021 12:00	0,587	0,627

21.08.2021 12:00	0,613	0,620
22.08.2021 12:00	0,601	0,622
23.08.2021 12:00	0,583	0,591
24.08.2021 12:00	0,544	0,591
25.08.2021 12:00	0,564	0,591
26.08.2021 12:00	0,563	0,582
27.08.2021 12:00	0,583	0,590
28.08.2021 12:00	0,495	0,563
29.08.2021 12:00	0,527	0,549
30.08.2021 12:00	0,517	0,551
31.08.2021 12:00	0,518	0,543
01.09.2021 12:00	0,508	0,536
02.09.2021 12:00	0,499	0,537
03.09.2021 12:00	0,445	0,539
04.09.2021 12:00	0,502	0,532
05.09.2021 12:00	0,466	0,517
06.09.2021 12:00	0,479	0,524
07.09.2021 12:00	0,410	0,539
08.09.2021 12:00	0,454	0,506
09.09.2021 12:00	0,492	0,511
10.09.2021 12:00	0,385	0,549
11.09.2021 12:00	0,373	0,546
12.09.2021 11:00	0,427	0,493
13.09.2021 12:00	0,375	0,518
14.09.2021 12:00	0,431	0,501
15.09.2021 12:00	0,371	0,511
16.09.2021 12:00	0,471	0,484
17.09.2021 12:00	0,464	0,502
18.09.2021 12:00	0,425	0,499
19.09.2021 12:00	0,454	0,484
20.09.2021 12:00	0,475	0,486

9.3 C – Normalized NDVI data

9.3.1 Rack 2, *Cassiope* site

Date:	Ambient:	Watered:
16.07.2021	0,73807587	0,6133548
17.07.2021	0,6431577	0,60631291
18.07.2021	0,74073883	0,62037323
19.07.2021	0,75692159	0,72950225
20.07.2021	0,78846035	0,68927329
21.07.2021	0,80532579	0,72950225
22.07.2021	0,74596481	0,73612695
23.07.2021	0,80037267	0,68927329
24.07.2021	0,80037267	0,6343397
25.07.2021	0,78393822	0,68248776
26.07.2021	0,70041335	0,749308
27.07.2021	0,82657087	0,67567912
28.07.2021	0,80864983	0,78830682
29.07.2021	0,85467483	0,77539743
30.07.2021	0,86607241	0,72285477
31.07.2021	0,79324824	0,69603535
01.08.2021	0,71504704	0,78186334
02.08.2021	0,76760114	0,64821267
03.08.2021	0,78194702	0,64821267
04.08.2021	0,72645115	0,79472785
05.08.2021	1	1
06.08.2021	0,76760114	0,68927329
07.08.2021	0,69138642	0,70277463
08.08.2021	0,68987214	0,71618451
09.08.2021	0,7657772	0,68927329
10.08.2021	0,72418845	0,64128808
11.08.2021	0,60053057	0,57790906
12.08.2021	0,8675841	0,93039715
13.08.2021	0,77478196	0,72950225
14.08.2021	0,62306885	0,71618451
15.08.2021	0,70773791	0,58504547
16.08.2021	0,6066828	0,6343397
17.08.2021	0,67489276	0,55635737
18.08.2021	0,6969799	0,48296649
19.08.2021	0,65266864	0,58504547
20.08.2021	0,57785879	0,57790906
21.08.2021	0,62306885	0,45293639
22.08.2021	0,62073997	0,43015897
23.08.2021	0,5507493	0,38394656
24.08.2021	0,50292872	0,39944851
25.08.2021	0,47032896	0,29692855

26.08.2021	0,44692464	0,29692855
27.08.2021	0,30611485	0,46048012
28.08.2021	0,27690486	0,39170995
29.08.2021	0,44904348	0,14805881
30.08.2021	0,39728553	0,13955082
31.08.2021	0,40738415	0,09663376
01.09.2021	0,40977832	0,06184695
02.09.2021	0,38144113	0,15654199
03.09.2021	0,14353804	0,2888697
04.09.2021	0,38937014	0,06184695
05.09.2021	0,32780014	0,01779665
06.09.2021	0,3415965	0,02665724
07.09.2021	0,06756701	0,2888697
08.09.2021	0,30366845	0
09.09.2021	0,24464661	0,01779665
10.09.2021	0,05995846	0,2069137
11.09.2021	0	0,1902231
12.09.2021	0,23085408	0
13.09.2021	0,04409233	0,2069137
14.09.2021	0,18158225	0,05308735
15.09.2021	0,0431108	0,24820281
16.09.2021	0,27942149	0,24820281
17.09.2021	0,2715778	0,16499967
18.09.2021	0,23085408	0,15654199
19.09.2021	0,39829756	0,25638576
20.09.2021	0,19549748	0,15654199

9.3.2 Rack 4, *Dryas* site

Date:	Ambient:	Watered:
16.07.2021 12:00	0,75868909	0,48686247
17.07.2021 12:00	0,79349724	0,58869511
18.07.2021 12:00	0,82328122	0,64305684
19.07.2021 12:00	0,85655471	0,68771705
20.07.2021 12:00	0,83585434	0,73179276
21.07.2021 12:00	0,90889676	0,75795715
22.07.2021 12:00	0,77619599	0,70541743
23.07.2021 12:00	0,81906488	0,66992287
24.07.2021 12:00	0,82748503	0,63405476
25.07.2021 12:00	0,8483127	0,72302435
26.07.2021 12:00	0,74985849	0,66992287
27.07.2021 12:00	0,85655471	0,71423257
28.07.2021 12:00	0,8930182	0,7925148
29.07.2021 12:00	0,8483127	0,73179276

30.07.2021 12:00	0,8728869	0,74925916
31.07.2021 12:00	0,80633869	0,77528302
01.08.2021 12:00	0,69579059	0,6609909
02.08.2021 12:00	0,76746831	0,62502931
03.08.2021 12:00	0,8483127	0,73179276
04.08.2021 12:00	0,72305693	0,69657892
05.08.2021 12:00	1	0,95153914
06.08.2021 12:00	0,81483547	0,53349689
07.08.2021 12:00	0,70036723	0,64305684
08.08.2021 12:00	0,70036723	0,6609909
09.08.2021 12:00	0,78054067	0,69657892
10.08.2021 12:00	0,69579059	0,61598081
11.08.2021 12:00	0,65401806	0,60690894
12.08.2021 12:00	0,96290232	1
13.08.2021 12:00	0,72305693	0,57955345
14.08.2021 12:00	0,58695651	0,51491234
15.08.2021 12:00	0,79349724	0,66992287
16.08.2021 12:00	0,65401806	0,60690894
17.08.2021 12:00	0,6912009	0,61598081
18.08.2021 12:00	0,71401981	0,57038843
19.08.2021 12:00	0,60154002	0,57955345
20.08.2021 12:00	0,57716974	0,53349689
21.08.2021 12:00	0,71401981	0,54275475
22.08.2021 12:00	0,70036723	0,56120036
23.08.2021 12:00	0,64459297	0,4774663
24.08.2021 12:00	0,50722136	0,4774663
25.08.2021 12:00	0,62080395	0,45860513
26.08.2021 12:00	0,57716974	0,54275475
27.08.2021 12:00	0,76308514	0,6788318
28.08.2021 12:00	0,29370868	0,15467123
29.08.2021 12:00	0,61119776	0,43965238
30.08.2021 12:00	0,56733125	0,43014159
31.08.2021 12:00	0,58695651	0,40147201
01.09.2021 12:00	0,54749998	0,37259749
02.09.2021 12:00	0,48677522	0,36292724
03.09.2021 12:00	0,22009449	0,26498367
04.09.2021 12:00	0,57225685	0,36292724
05.09.2021 12:00	0,53750738	0,30443076
06.09.2021 12:00	0,47647562	0,27487891
07.09.2021 12:00	0,11491621	0,1445109
08.09.2021 12:00	0,5173679	0,29460262
09.09.2021 12:00	0,61119776	0,36292724
10.09.2021 12:00	0,07904714	0,08309273
11.09.2021 12:00	0,06096533	0,08309273
12.09.2021 12:00	0,35440714	0,07278082
13.09.2021 12:00	0,02451247	0

14.09.2021 12:00	0,37070371	0,30443076
15.09.2021 12:00	0	0,0104608
16.09.2021 12:00	0,68659832	0,40147201
17.09.2021 12:00	0,53750738	0,34351867
18.09.2021 12:00	0,22582825	0,08309273
19.09.2021 12:00	0,71401981	0,43014159
20.09.2021 12:00	0,63035843	0,53349689

9.3.3 Rack 6, *Salix* site

Date:	Ambient:	Watered:
16.07.2021 12:00	0,90823066	0,85802967
17.07.2021 12:00	0,88130099	0,91947041
18.07.2021 12:00	0,97603436	0,96730876
19.07.2021 12:00	0,99474165	0,99678545
20.07.2021 12:00	0,96238056	0,97394421
21.07.2021 12:00	1	0,98380616
22.07.2021 12:00	0,96513082	1
23.07.2021 12:00	0,96787141	0,97724381
24.07.2021 12:00	0,95685024	0,91595919
25.07.2021 12:00	0,95962031	0,91595919
26.07.2021 12:00	0,89636501	0,96730876
27.07.2021 12:00	0,96238056	0,91947041
28.07.2021 12:00	0,96787141	0,91243522
29.07.2021 12:00	0,91702247	0,92992813
30.07.2021 12:00	0,92572291	0,87648933
31.07.2021 12:00	0,89037045	0,8728236
01.08.2021 12:00	0,83773275	0,92992813
02.08.2021 12:00	0,87213815	0,84679596
03.08.2021 12:00	0,87213815	0,87648933
04.08.2021 12:00	0,83454143	0,86545286
05.08.2021 12:00	0,99474165	0,8801421
06.08.2021 12:00	0,86597728	0,85802967
07.08.2021 12:00	0,7718654	0,80848563
08.08.2021 12:00	0,81190339	0,7808663
09.08.2021 12:00	0,83454143	0,7808663
10.08.2021 12:00	0,74778381	0,72778877
11.08.2021 12:00	0,65357503	0,67669821
12.08.2021 12:00	0,87213815	0,70674799
13.08.2021 12:00	0,75817044	0,68966171
14.08.2021 12:00	0,66856181	0,69395439
15.08.2021 12:00	0,73378064	0,65038645
16.08.2021 12:00	0,66483193	0,65921421
17.08.2021 12:00	0,63840765	0,60080313

18.08.2021 12:00	0,65357503	0,56363837
19.08.2021 12:00	0,60361833	0,56833525
20.08.2021 12:00	0,55579961	0,48648533
21.08.2021 12:00	0,62305922	0,46159637
22.08.2021 12:00	0,59181733	0,46660389
23.08.2021 12:00	0,54767029	0,36360931
24.08.2021 12:00	0,44655997	0,36360931
25.08.2021 12:00	0,51592571	0,36360931
26.08.2021 12:00	0,49371712	0,33154016
27.08.2021 12:00	0,54767029	0,35830208
28.08.2021 12:00	0,32034937	0,26577717
29.08.2021 12:00	0,4024977	0,22073257
30.08.2021 12:00	0,37551828	0,22641564
31.08.2021 12:00	0,38004303	0,19785022
01.09.2021 12:00	0,35272651	0,17472851
02.09.2021 12:00	0,32965564	0,18053126
03.09.2021 12:00	0,19043085	0,18631923
04.09.2021 12:00	0,33891745	0,16307804
05.09.2021 12:00	0,24431438	0,10991384
06.09.2021 12:00	0,27792453	0,13369085
07.09.2021 12:00	0,09951313	0,18631923
08.09.2021 12:00	0,21508379	0,07380433
09.09.2021 12:00	0,3109988	0,09192561
10.09.2021 12:00	0,03707343	0,22073257
11.09.2021 12:00	0,00532492	0,20932126
12.09.2021 12:00	0,14539127	0,03100742
13.09.2021 12:00	0,01064032	0,11588042
14.09.2021 12:00	0,15547314	0,05555081
15.09.2021 12:00	0	0,09192561
16.09.2021 12:00	0,25878394	0
17.09.2021 12:00	0,23946952	0,06165003
18.09.2021 12:00	0,14033471	0,04943691
19.09.2021 12:00	0,21508379	0
20.09.2021 12:00	0,26837608	0,00623054

9.4 D – Soil moisture data

9.4.1 Rack 2, *Cassiope* site

Date:	Ambient:	Watered:
16.07.2021 12:00	0,2930924	0,16879143
17.07.2021 12:00	0,23376168	0,16716245
18.07.2021 12:00	0,22953999	0,16634586
19.07.2021 12:00	0,25420466	0,19641185
20.07.2021 12:00	0,24886031	0,23515894
21.07.2021 12:00	0,24852373	0,23271048
22.07.2021 12:00	0,24377969	0,24446106
23.07.2021 12:00	0,24138527	0,24104197
24.07.2021 12:00	0,24104197	0,24001028
25.07.2021 12:00	0,23966575	0,24241328
26.07.2021 12:00	0,2372455	0,24001028
27.07.2021 12:00	0,2382846	0,23863035
28.07.2021 12:00	0,2358557	0,23689851
29.07.2021 12:00	0,23966575	0,24001028
30.07.2021 12:00	0,2372455	0,23376168
31.07.2021 12:00	0,23095223	0,25354084
01.08.2021 12:00	0,22883199	0,23793855
02.08.2021 12:00	0,22670044	0,23620361
03.08.2021 12:00	0,22918615	0,23376168
04.08.2021 12:00	0,22096063	0,23411147
05.08.2021 12:00	0,25979921	0,25585905
06.08.2021 12:00	0,2348101	0,23863035
07.08.2021 12:00	0,2334116	0,24035448
08.08.2021 12:00	0,22953999	0,23863035
09.08.2021 12:00	0,22883199	0,23689851
10.08.2021 12:00	0,22847752	0,23515894
11.08.2021 12:00	0,22598739	0,25618902
12.08.2021 12:00	0,24377969	0,2358557
13.08.2021 12:00	0,24412052	0,2382846
14.08.2021 12:00	0,23515894	0,23932093
15.08.2021 12:00	0,23306119	0,24035448
16.08.2021 12:00	0,23095223	0,23863035
17.08.2021 12:00	0,22989352	0,23759218
18.08.2021 12:00	0,22953999	0,24751216
19.08.2021 12:00	0,22776763	0,2382846
20.08.2021 12:00	0,22527309	0,23655123
21.08.2021 12:00	0,22634408	0,23515894
22.08.2021 12:00	0,22384068	0,23759218
23.08.2021 12:00	0,22204304	0,2358557
24.08.2021 12:00	0,22276305	0,23446093
25.08.2021 12:00	0,2224032	0,23411147
26.08.2021 12:00	0,22168255	0,23306119

27.08.2021 12:00	0,2640197	0,2528758
28.08.2021 12:00	0,2348101	0,23759218
29.08.2021 12:00	0,23411147	0,23655123
30.08.2021 12:00	0,23655123	0,23655123
31.08.2021 12:00	0,23550747	0,23655123
01.09.2021 12:00	0,23655123	0,23689851
02.09.2021 12:00	0,23550747	0,23655123
03.09.2021 12:00	0,22348179	0,2382846
04.09.2021 12:00	0,22776763	0,23897579
05.09.2021 12:00	0,23306119	0,23759218
06.09.2021 12:00	0,23376168	0,23759218
07.09.2021 12:00	0,23306119	0,2372455
08.09.2021 12:00	0,21440575	0,23689851
09.09.2021 12:00	0,23446093	0,23759218
10.09.2021 12:00	0,23411147	0,23655123
11.09.2021 12:00	0,2224032	0,23655123
12.09.2021 12:00	0,20437708	0,23932093
13.09.2021 12:00	0,19908313	0,23897579
14.09.2021 12:00	0,17805076	0,22598739
15.09.2021 12:00	0,18946789	0,22812273
16.09.2021 12:00	0,18201995	0,21696723
17.09.2021 12:00	0,19832157	0,2358557
18.09.2021 12:00	0,213671	0,23897579
19.09.2021 12:00	0,23550747	0,23689851
20.09.2021 12:00	0,23024674	0,24069838

9.4.2 Rack 4, *Dryas* site

Date:	Ambient:	Watered:
16.07.2021 12:00	0,08695067	0,1683847
17.07.2021 12:00	0,07447901	0,1683847
18.07.2021 12:00	0,07253694	0,16388777
19.07.2021 12:00	0,09869698	0,25120795
20.07.2021 12:00	0,08979163	0,23966575
21.07.2021 12:00	0,09026378	0,1219262
22.07.2021 12:00	0,08837288	0,1683847
23.07.2021 12:00	0,08552499	0,15976298
24.07.2021 12:00	0,08457261	0,15602063
25.07.2021 12:00	0,08266322	0,16347687
26.07.2021 12:00	0,0821849	0,15810324
27.07.2021 12:00	0,07786259	0,15476683
28.07.2021 12:00	0,07544769	0,15140776
29.07.2021 12:00	0,07641482	0,16347687
30.07.2021 12:00	0,07930686	0,1585187
31.07.2021 12:00	0,08695067	0,18003961

01.08.2021 12:00	0,08457261	0,16182975
02.08.2021 12:00	0,08266322	0,15643786
03.08.2021 12:00	0,08361869	0,15182889
04.08.2021 12:00	0,08647583	0,15140776
05.08.2021 12:00	0,08789919	0,17805076
06.08.2021 12:00	0,09962638	0,16675434
07.08.2021 12:00	0,09776606	0,17444924
08.08.2021 12:00	0,08361869	0,1651184
09.08.2021 12:00	0,0821849	0,1610041
10.08.2021 12:00	0,0812271	0,1585187
11.08.2021 12:00	0,0797875	0,17884733
12.08.2021 12:00	0,09120692	0,16182975
13.08.2021 12:00	0,10194323	0,17000952
14.08.2021 12:00	0,0893191	0,16429833
15.08.2021 12:00	0,08695067	0,1651184
16.08.2021 12:00	0,0817062	0,16182975
17.08.2021 12:00	0,08026776	0,15934858
18.08.2021 12:00	0,07930686	0,18122883
19.08.2021 12:00	0,07786259	0,16224207
20.08.2021 12:00	0,0783444	0,15810324
21.08.2021 12:00	0,07593145	0,15643786
22.08.2021 12:00	0,07544769	0,16306561
23.08.2021 12:00	0,07496355	0,1585187
24.08.2021 12:00	0,07447901	0,15810324
25.08.2021 12:00	0,07399408	0,15643786
26.08.2021 12:00	0,07350875	0,15476683
27.08.2021 12:00	0,09214853	0,17444924
28.08.2021 12:00	0,08361869	0,16388777
29.08.2021 12:00	0,08361869	0,15727125
30.08.2021 12:00	0,09261876	0,1585187
31.08.2021 12:00	0,09167791	0,15643786
01.09.2021 12:00	0,08647583	0,15518512
02.09.2021 12:00	0,07786259	0,15350984
03.09.2021 12:00	0,07786259	0,14717691
04.09.2021 12:00	0,0797875	0,1497197
05.09.2021 12:00	0,08074763	0,14887352
06.09.2021 12:00	0,0821849	0,14802593
07.09.2021 12:00	0,0783444	0,1459007
08.09.2021 12:00	0,07253694	0,13730989
09.09.2021 12:00	0,07156356	0,14248165
10.09.2021 12:00	0,07302304	0,14248165
11.09.2021 12:00	0,07010055	0,13296025
12.09.2021 12:00	0,0647059	0,12459532
13.09.2021 12:00	0,06273238	0,11383884
14.09.2021 12:00	0,05777086	0,07350875
15.09.2021 12:00	0,05677379	0,08266322

16.09.2021 12:00	0,0582688	0,07399408
17.09.2021 12:00	0,068634	0,08979163
18.09.2021 12:00	0,0666731	0,13557439
19.09.2021 12:00	0,08314115	0,15098627
20.09.2021 12:00	0,07544769	0,14802593

9.5 E – Normalized soil moisture data

9.5.1 Rack 2, *Cassiope* site

Date:	Ambient:	Watered:
16.07.2021	1	0,02722037
17.07.2021	0,48426748	0,00908899
18.07.2021	0,4475704	0
19.07.2021	0,66196815	0,33464969
20.07.2021	0,6155124	0,76592448
21.07.2021	0,61258661	0,73867193
22.07.2021	0,57134904	0,86946185
23.07.2021	0,55053551	0,83140568
24.07.2021	0,54755143	0,81992237
25.07.2021	0,53558858	0,84666905
26.07.2021	0,51455057	0,81992237
27.07.2021	0,52358298	0,80456314
28.07.2021	0,50246972	0,78528685
29.07.2021	0,53558858	0,81992237
30.07.2021	0,51455057	0,75037235
31.07.2021	0,45984632	0,97052447
01.08.2021	0,44141611	0,79686304
02.08.2021	0,42288759	0,77755225
03.08.2021	0,44449462	0,75037235
04.08.2021	0,37299428	0,75426569
05.08.2021	0,71059882	0,99632725
06.08.2021	0,49338084	0,80456314
07.08.2021	0,48122434	0,82375351
08.08.2021	0,4475704	0,80456314
09.08.2021	0,44141611	0,78528685
10.08.2021	0,43833489	0,76592448
11.08.2021	0,4166894	1
12.08.2021	0,57134904	0,77367981
13.08.2021	0,57431174	0,80071475
14.08.2021	0,4964131	0,81224964
15.08.2021	0,47817848	0,82375351
16.08.2021	0,45984632	0,80456314
17.08.2021	0,45064346	0,79300768
18.08.2021	0,4475704	0,90342217
19.08.2021	0,43216416	0,80071475
20.08.2021	0,41048033	0,78142137
21.08.2021	0,41978992	0,76592448
22.08.2021	0,39802915	0,79300768
23.08.2021	0,3824031	0,77367981
24.08.2021	0,38866178	0,75815538
25.08.2021	0,3855338	0,75426569
26.08.2021	0,37926955	0,74257555

27.08.2021	0,74728541	0,96312225
28.08.2021	0,49338084	0,79300768
29.08.2021	0,48730803	0,78142137
30.08.2021	0,50851559	0,78142137
31.08.2021	0,49944277	0,78142137
01.09.2021	0,50851559	0,78528685
02.09.2021	0,49944277	0,78142137
03.09.2021	0,39490946	0,80071475
04.09.2021	0,43216416	0,80840805
05.09.2021	0,47817848	0,79300768
06.09.2021	0,48426748	0,79300768
07.09.2021	0,47817848	0,78914901
08.09.2021	0,3160159	0,78528685
09.09.2021	0,49034573	0,79300768
10.09.2021	0,48730803	0,78142137
11.09.2021	0,3855338	0,78142137
12.09.2021	0,22884173	0,81224964
13.09.2021	0,18282404	0,80840805
14.09.2021	0	0,66384051
15.09.2021	0,0992435	0,68760789
16.09.2021	0,03450222	0,56344149
17.09.2021	0,1762041	0,77367981
18.09.2021	0,30962912	0,80840805
19.09.2021	0,49944277	0,78528685
20.09.2021	0,4537138	0,82758134

9.5.2 Rack 4, *Dryas* site

Date:	Ambient:	Watered:
16.07.2021 12:00	0,66808186	0,53391321
17.07.2021 12:00	0,39197333	0,53391321
18.07.2021 12:00	0,34897815	0,50726104
19.07.2021 12:00	0,92813177	1
20.07.2021 12:00	0,73097728	0,93504641
21.07.2021 12:00	0,74143016	0,27246859
22.07.2021 12:00	0,69956784	0,53391321
23.07.2021 12:00	0,63651885	0,48539457
24.07.2021 12:00	0,61543429	0,46433453
25.07.2021 12:00	0,5731624	0,50629445
26.07.2021 12:00	0,56257295	0,47605443
27.07.2021 12:00	0,46688203	0,4572788
28.07.2021 12:00	0,41341896	0,4383757
29.07.2021 12:00	0,43483012	0,50629445
30.07.2021 12:00	0,49885642	0,47839242
31.07.2021 12:00	0,66808186	0,59950109

01.08.2021 12:00	0,61543429	0,49702533
02.08.2021 12:00	0,5731624	0,4666825
03.08.2021 12:00	0,59431542	0,44074556
04.08.2021 12:00	0,65756943	0,4383757
05.08.2021 12:00	0,68908098	0,58830882
06.08.2021 12:00	0,94870747	0,52473835
07.08.2021 12:00	0,90752226	0,5680413
08.08.2021 12:00	0,59431542	0,51553212
09.08.2021 12:00	0,56257295	0,49237895
10.08.2021 12:00	0,54136847	0,47839242
11.08.2021 12:00	0,50949734	0,59279151
12.08.2021 12:00	0,76231019	0,49702533
13.08.2021 12:00	1	0,54305688
14.08.2021 12:00	0,72051599	0,51091718
15.08.2021 12:00	0,66808186	0,51553212
16.08.2021 12:00	0,55197508	0,49702533
17.08.2021 12:00	0,52012968	0,48306254
18.08.2021 12:00	0,49885642	0,60619339
19.08.2021 12:00	0,46688203	0,49934563
20.08.2021 12:00	0,47754885	0,47605443
21.08.2021 12:00	0,42412883	0,4666825
22.08.2021 12:00	0,41341896	0,5039801
23.08.2021 12:00	0,40270052	0,47839242
24.08.2021 12:00	0,39197333	0,47605443
25.08.2021 12:00	0,38123757	0,4666825
26.08.2021 12:00	0,37049306	0,4572788
27.08.2021 12:00	0,7831564	0,5680413
28.08.2021 12:00	0,59431542	0,50860678
29.08.2021 12:00	0,59431542	0,47137241
30.08.2021 12:00	0,79356672	0,47839242
31.08.2021 12:00	0,7727375	0,4666825
01.09.2021 12:00	0,65756943	0,45963272
02.09.2021 12:00	0,46688203	0,45020512
03.09.2021 12:00	0,46688203	0,41456661
04.09.2021 12:00	0,50949734	0,42887615
05.09.2021 12:00	0,53075345	0,4241143
06.09.2021 12:00	0,56257295	0,41934448
07.09.2021 12:00	0,47754885	0,40738475
08.09.2021 12:00	0,34897815	0,35904012
09.09.2021 12:00	0,3274286	0,38814414
10.09.2021 12:00	0,35973998	0,38814414
11.09.2021 12:00	0,29503921	0,33456252
12.09.2021 12:00	0,17560791	0,28748902
13.09.2021 12:00	0,13191649	0,22695708
14.09.2021 12:00	0,022074	0
15.09.2021 12:00	0	0,05151662

16.09.2021 12:00	0,03309776	0,00273115
17.09.2021 12:00	0,26257146	0,09163166
18.09.2021 12:00	0,21915946	0,34927357
19.09.2021 12:00	0,58374328	0,43600375
20.09.2021 12:00	0,41341896	0,41934448

9.6 F – Soil temperature data

9.6.1 Rack 2, *Cassiope* site

Date:	Ambient:	Watered:
16.07.2021 12:00	7,7	7,0
17.07.2021 12:00	8,8	8,0
18.07.2021 12:00	6,8	6,3
19.07.2021 12:00	5,3	6,1
20.07.2021 12:00	5,4	5,7
21.07.2021 12:00	4,8	5,2
22.07.2021 12:00	6,1	7,0
23.07.2021 12:00	6,3	7,2
24.07.2021 12:00	6,9	7,8
25.07.2021 12:00	6,6	7,3
26.07.2021 12:00	8,3	8,9
27.07.2021 12:00	7,0	8,1
28.07.2021 12:00	6,4	6,7
29.07.2021 12:00	6,7	8,0
30.07.2021 12:00	6,7	7,1
31.07.2021 12:00	4,8	5,1
01.08.2021 12:00	5,8	6,7
02.08.2021 12:00	6,2	6,9
03.08.2021 12:00	5,3	5,4
04.08.2021 12:00	6,3	7,3
05.08.2021 12:00	5,7	6,0
06.08.2021 12:00	6,5	7,4
07.08.2021 12:00	7,1	8,5
08.08.2021 12:00	6,9	8,2
09.08.2021 12:00	6,6	7,6
10.08.2021 12:00	7,0	7,9
11.08.2021 12:00	7,7	8,8
12.08.2021 12:00	7,1	7,3
13.08.2021 12:00	6,4	6,8
14.08.2021 12:00	4,6	5,6
15.08.2021 12:00	5,1	5,5
16.08.2021 12:00	5,1	6,5
17.08.2021 12:00	5,2	5,6
18.08.2021 12:00	5,7	6,5
19.08.2021 12:00	5,3	5,7
20.08.2021 12:00	4,1	5,0
21.08.2021 12:00	4,9	6,0
22.08.2021 12:00	4,5	5,1
23.08.2021 12:00	4,9	5,2
24.08.2021 12:00	5,2	6,2
25.08.2021 12:00	5,9	6,6
26.08.2021 12:00	5,2	5,7

27.08.2021 12:00	5,1	5,3
28.08.2021 12:00	4,1	4,9
29.08.2021 12:00	4,2	4,6
30.08.2021 12:00	5,2	5,5
31.08.2021 12:00	4,9	5,2
01.09.2021 12:00	4,1	4,5
02.09.2021 12:00	3,7	4,1
03.09.2021 12:00	1,1	1,0
04.09.2021 12:00	0,7	0,8
05.09.2021 12:00	1,8	2,0
06.09.2021 12:00	2,0	2,4
07.09.2021 12:00	1,0	1,3
08.09.2021 12:00	0,6	0,5
09.09.2021 12:00	0,8	1,2
10.09.2021 12:00	1,5	1,8
11.09.2021 12:00	0,5	0,4
12.09.2021 12:00	0,2	0,3
13.09.2021 12:00	0,2	0,3
14.09.2021 12:00	0,2	0,2
15.09.2021 12:00	0,2	0,2
16.09.2021 12:00	0,2	0,2
17.09.2021 12:00	0,2	0,2
18.09.2021 12:00	0,7	1,5
19.09.2021 12:00	4,1	4,6
20.09.2021 12:00	2,7	2,9

9.6.2 Rack 4, *Dryas* site

Date:	Ambient:	Watered:
16.07.2021 12:00	8,5	8,7
17.07.2021 12:00	9,2	10,2
18.07.2021 12:00	7,8	8,0
19.07.2021 12:00	5,5	7,3
20.07.2021 12:00	6,2	6,5
21.07.2021 12:00	5,2	6,3
22.07.2021 12:00	6,6	8,3
23.07.2021 12:00	7,0	8,5
24.07.2021 12:00	7,6	9,1
25.07.2021 12:00	7,2	8,4
26.07.2021 12:00	8,6	9,8
27.07.2021 12:00	7,5	9,7
28.07.2021 12:00	7,0	7,7
29.07.2021 12:00	7,1	9,4
30.07.2021 12:00	7,1	8,2
31.07.2021 12:00	5,2	5,8

01.08.2021 12:00	6,2	7,7
02.08.2021 12:00	6,6	8,2
03.08.2021 12:00	5,7	6,2
04.08.2021 12:00	6,5	8,6
05.08.2021 12:00	6,2	6,9
06.08.2021 12:00	6,8	8,8
07.08.2021 12:00	7,7	9,3
08.08.2021 12:00	7,5	9,2
09.08.2021 12:00	7,2	8,9
10.08.2021 12:00	7,5	9,1
11.08.2021 12:00	8,5	9,7
12.08.2021 12:00	7,9	8,2
13.08.2021 12:00	6,7	7,6
14.08.2021 12:00	5,1	6,1
15.08.2021 12:00	5,7	6,1
16.08.2021 12:00	5,6	7,4
17.08.2021 12:00	5,5	6,6
18.08.2021 12:00	6,2	7,4
19.08.2021 12:00	5,7	6,4
20.08.2021 12:00	4,6	5,5
21.08.2021 12:00	5,3	6,8
22.08.2021 12:00	5,0	6,0
23.08.2021 12:00	5,3	6,0
24.08.2021 12:00	5,7	7,2
25.08.2021 12:00	6,2	7,7
26.08.2021 12:00	5,9	6,7
27.08.2021 12:00	5,4	6,0
28.08.2021 12:00	4,5	5,2
29.08.2021 12:00	4,9	5,3
30.08.2021 12:00	5,7	6,5
31.08.2021 12:00	5,3	6,0
01.09.2021 12:00	4,5	5,3
02.09.2021 12:00	4,1	4,8
03.09.2021 12:00	1,4	1,0
04.09.2021 12:00	1,4	1,0
05.09.2021 12:00	2,3	2,5
06.09.2021 12:00	2,4	3,0
07.09.2021 12:00	1,6	1,5
08.09.2021 12:00	0,9	0,7
09.09.2021 12:00	1,8	1,7
10.09.2021 12:00	2,2	2,1
11.09.2021 12:00	0,9	0,6
12.09.2021 12:00	0,7	0,5
13.09.2021 12:00	0,6	0,4
14.09.2021 12:00	0,5	0,3
15.09.2021 12:00	0,6	0,4

16.09.2021 12:00	0,6	0,3
17.09.2021 12:00	2,1	0,7
18.09.2021 12:00	2,5	1,9
19.09.2021 12:00	5,2	5,5
20.09.2021 12:00	3,4	3,5