INDIVIDUAL AND INTERACTIVE EFFECTS OF ELEVATED CO2, WARMING AND DROUGHT ON THE PHENOLOGY OF MOUNTAIN GRASSLAND

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This presentation participates in OSPP

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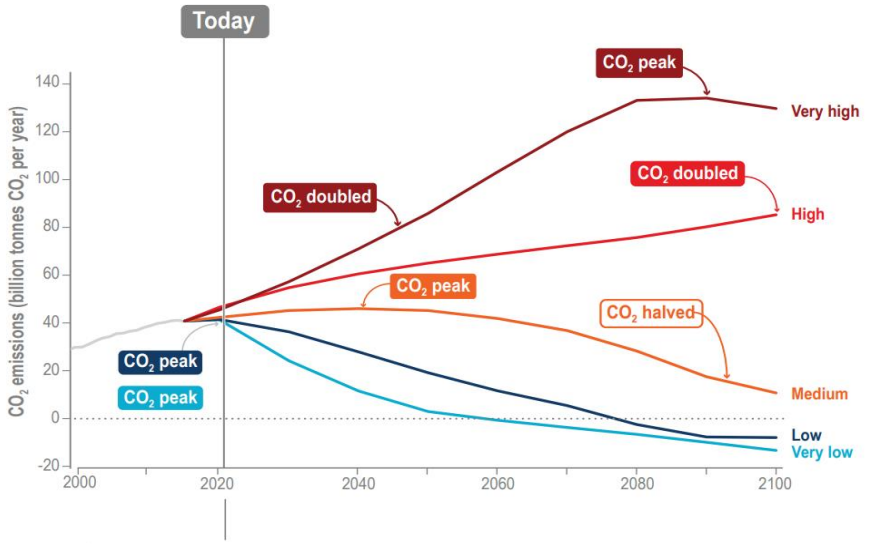
IPCC, 2021

Climate futures

The climate change that people will experience this century and beyond depends on our **greenhouse gases emissions**, how much **global warming this will cause** and the **response of the climate system** to this warming.

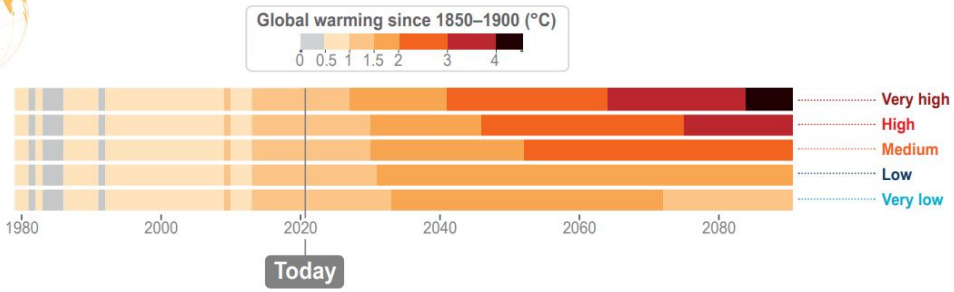
Emissions pathways

Different social and economic developments can lead to substantially different future emissions of carbon dioxide (CO_2), other greenhouse gases and air pollutants for the rest of the century.



Effect on surface temperature

For temperature to stabilize, CO_2 emissions need to reach net zero.



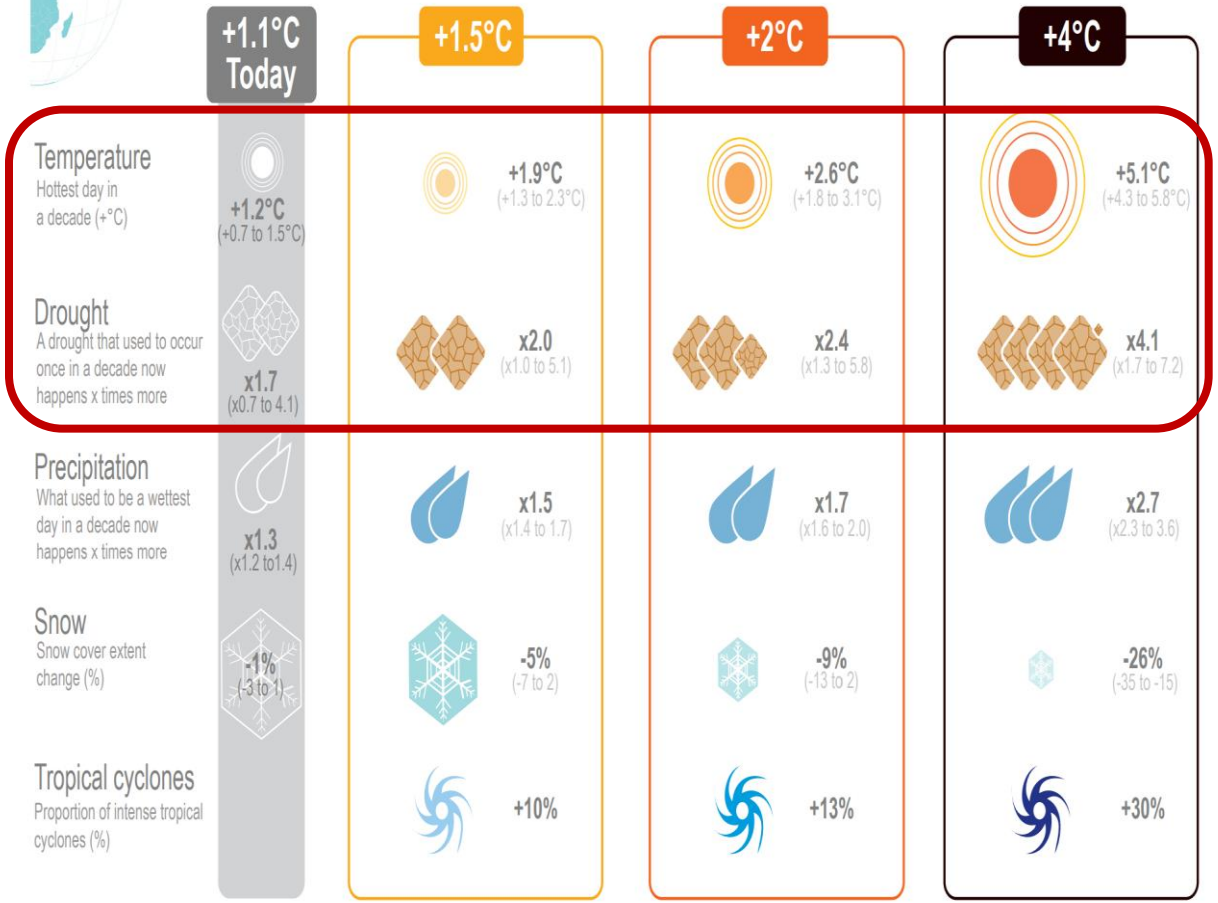
Short-term effect: Natural variability

Over short time scales (typically a decade), natural variability can temporarily dampen or accentuate global warming trends resulting from emissions.

Infographic TS.1 | Climate Futures. *The intent of this figure is to show possible climate futures: The climate change that people will experience this century and beyond depends on our greenhouse gas emissions, how much global warming this will cause and the response of the climate system to this warming.*
(top left) Annual emissions of CO_2 for the five core Shared Socio-economic Pathway (SSP) scenarios (very low: SSP1-1.9, low: SSP1-2.6, intermediate: SSP2-4.5, high: SSP3-7.0, very high: SSP5-8.5).**(bottom left)** Projected warming for each of these emissions scenarios.

Response of the climate system relative to 1850–1900

Many aspects of the climate system react quickly to temperature changes.
At progressively higher levels of global warming there are greater consequences (min/max range shown).

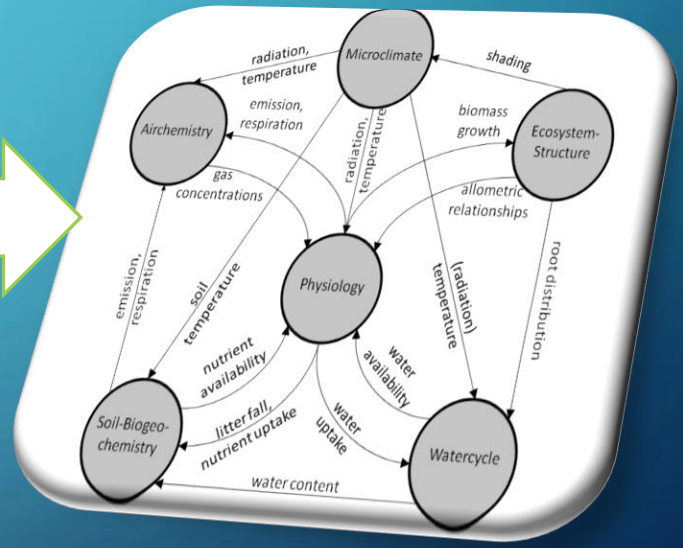


INTRODUCTION

IPCC, 2021 report states

carbon dioxide (CO2) is the main driver of global change.

chances of crossing the **global warming** level of 1.5°C in the next decades are evident.



even relatively small incremental increases in global warming (+0.5C) cause a **worsening of droughts**.

Affects Ecosystem Processes

Image courtesy: google images

PHENOLOGY

- Phenology is the study of periodically recurring patterns of growth and development of plants and animal behavior during the year.
- It is important for
  - plant functioning
  - ecosystem services and
  - their biophysical and biogeochemical feedbacks to the climate system.

Impact of Climate Change on Phenology

spring advancement - leaf emergence

autumn postponement of leaf senescence

Affect timing of flowering

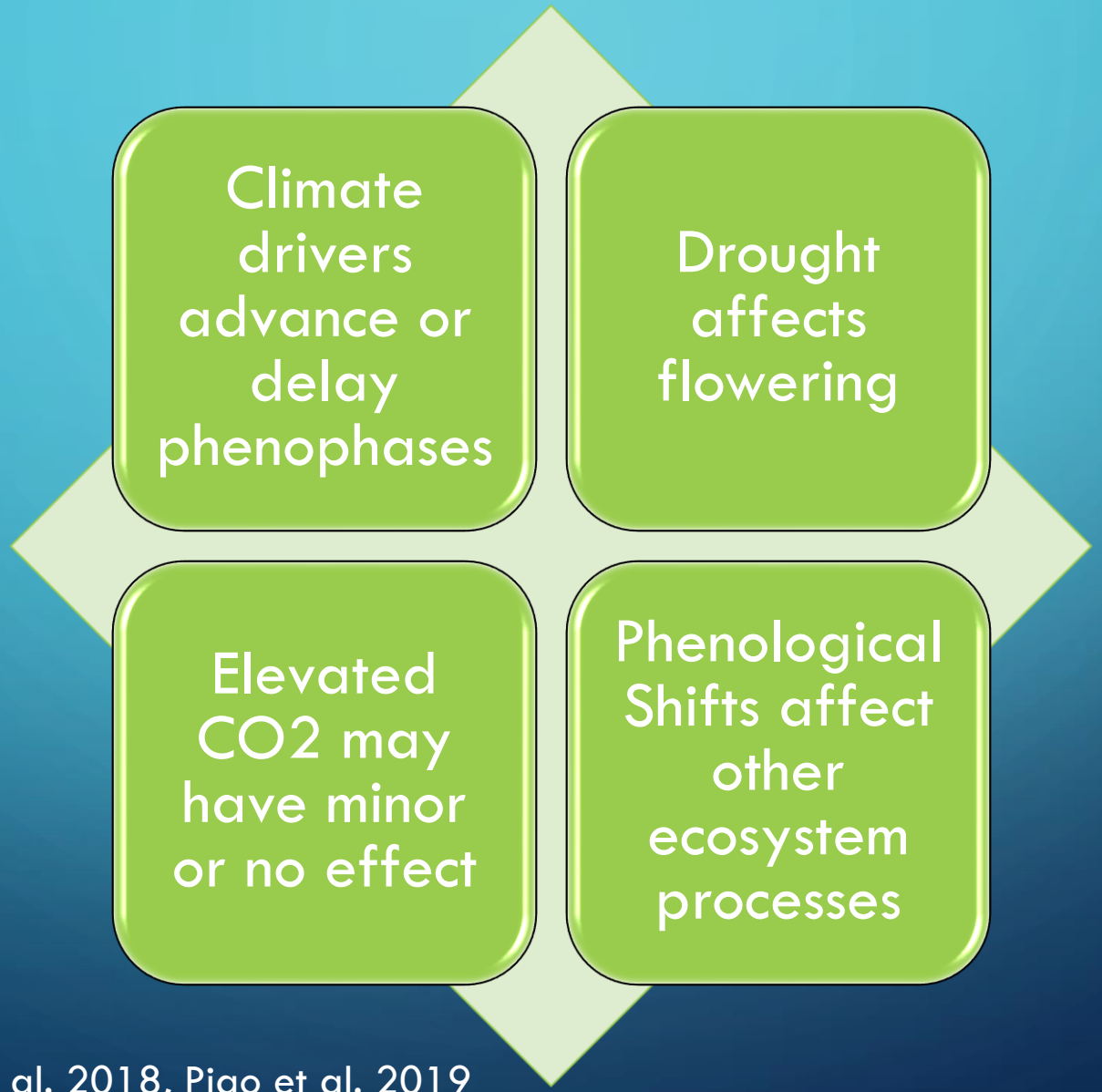
Has consequences for ecosystem productivity

Could shift the timing of major phenological events

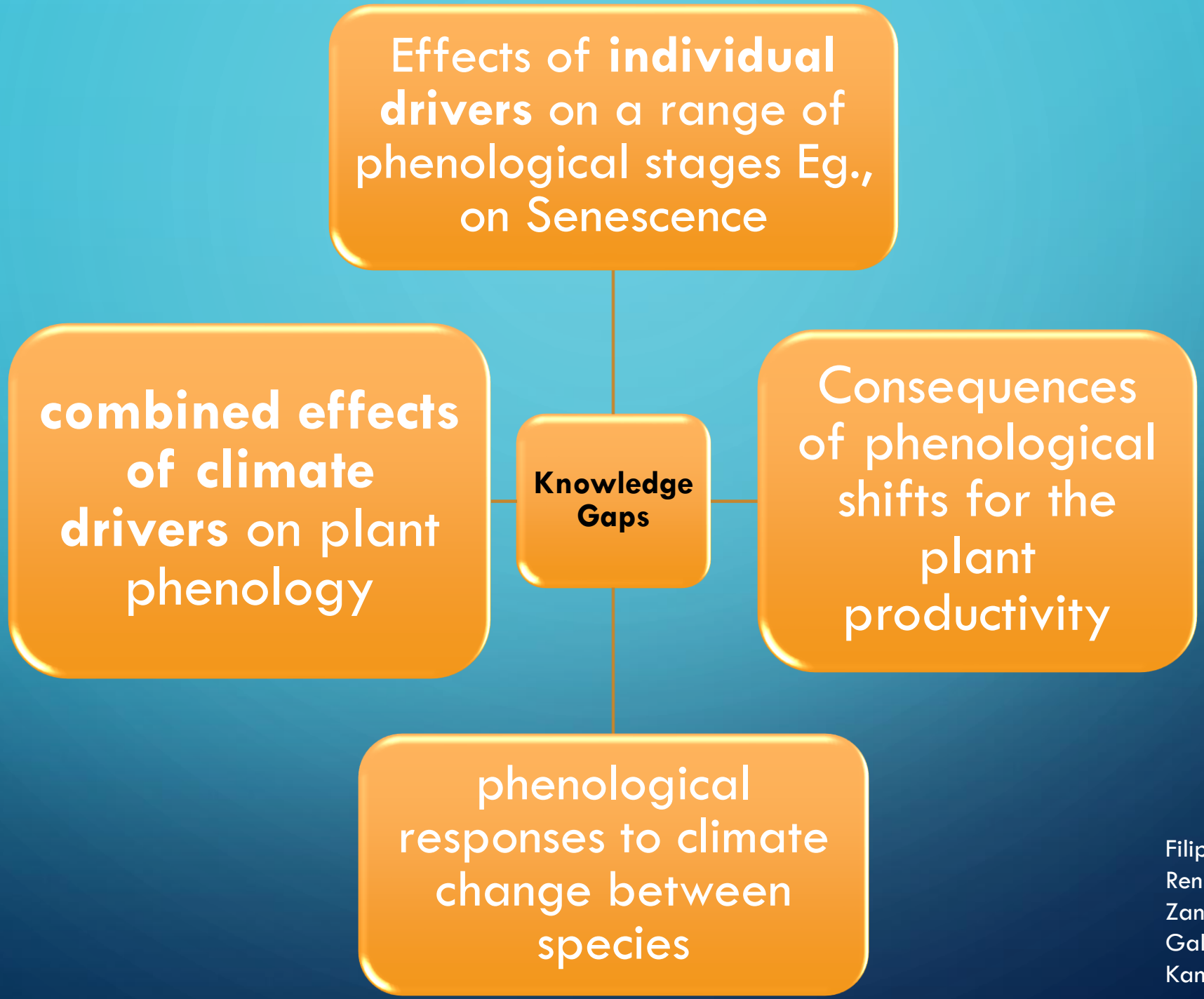
Image courtesy: google images

Piao et al. 2019, Huang et al. 2020, Gallinat et al. 2015, Richardson et al. 2018, Piao et al. 2019

WE KNOW FROM PREVIOUS STUDIES



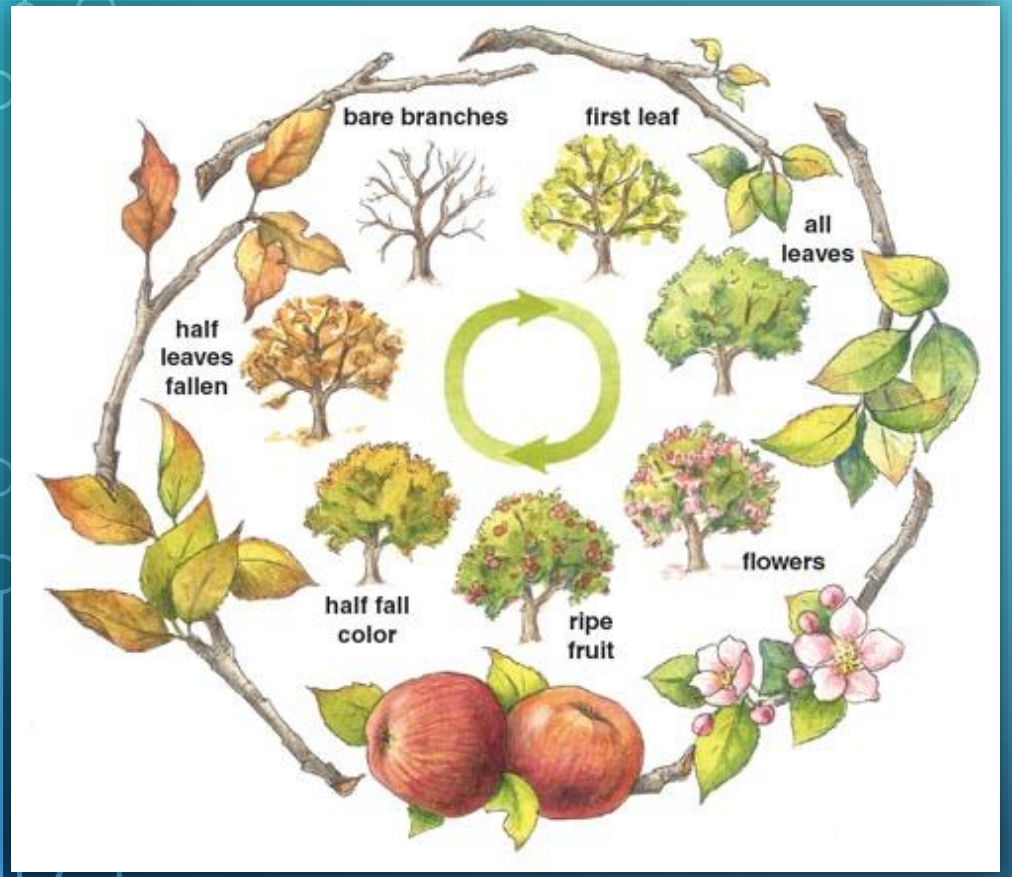
Gallinat et al. 2015, Richardson et al. 2018, Piao et al. 2019



Filippa et al. 2015,
Ren et al. 2020,
Zani et al. 2020,
Gallinat et al. 2015,
Kang et al. 2018

RESEARCH QUESTIONS

Phenology a **"leading indicator"** of climate change impacts.



1. What is the individual **VS** interactive effect of climate change drivers on the phenology of grasses?

2. Which climate change driver has a key effect on the phenology?

Image: https://www.americanscientist.org/sites/americanscientist.org/files/201381173919820-2013-09HavensF3.jpg

(usanpn.org)

HYPOTHESES

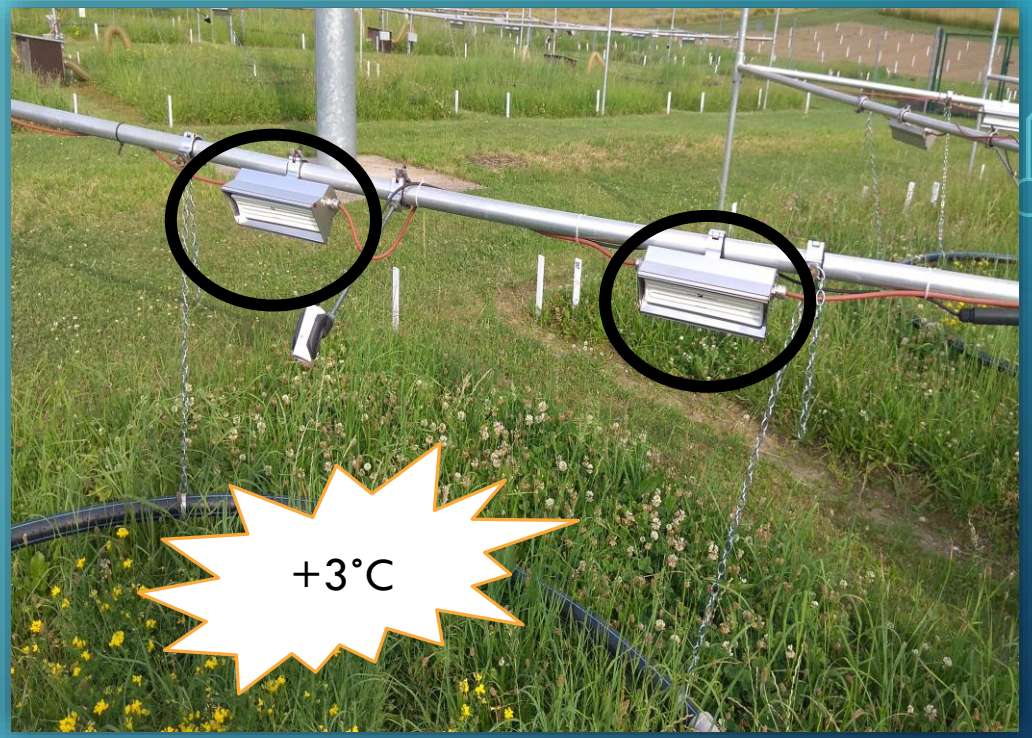
1. Climate warming causes early leaf emergence, early flowering and delayed senescence.
2. Elevated CO2 induces early spring phenology. Higher CO2 levels advance autumn phenology and accelerate leaf senescence.
3. Extreme drought delays leaf emergence, but advances flower onset and leaf senescence.
4. eCO2 and warming together advance spring phenology and contribute to a longer growing season by delaying plant maturation and senescence.
5. eCO2, warming and drought combined, advance leaf emergence, flowering, leaf colouring and senescence, the effect being additive rather than antagonistic or synergistic.

EXPERIMENT

IS BASED ON THE **CLIMGRASS EXPERIMENT.**

- managed C3 grassland typical for many European mountain regions.
- follows a multifactor, multilevel approach combining three levels of warming, atmospheric CO2 as well as precipitation manipulations involving automated rain-out shelters.
- facility includes 54 plots testing effects of global change under current and future climate conditions.

EXPERIMENTAL SETUP



FUTURE CLIMATE

EXPERIMENTAL SETUP EXPLAINED

- CO2 enrichment was achieved via a mini free air CO2 enrichment (FACE) system, which fumigates the plot during daytime through a circular tube surrounding the plots.
- Infrared lamps were used to heat the canopy surface temperature 3°C above ambient temperature.
- Mock frames and fumigation rings and mock IR-lamps were installed in all control plots to ensure that environmental conditions in plots differed only concerning the tested environmental drivers.

Meeran K et al. 2021

TREATMENTS STUDIED FOR THIS EXPERIMENT

A Ambient/Control

C Elevated CO2 at +300 ppm

T Elevated temperature at 3°C

D Drought – using rainout shelters during Jun to Jul

Individual Effect

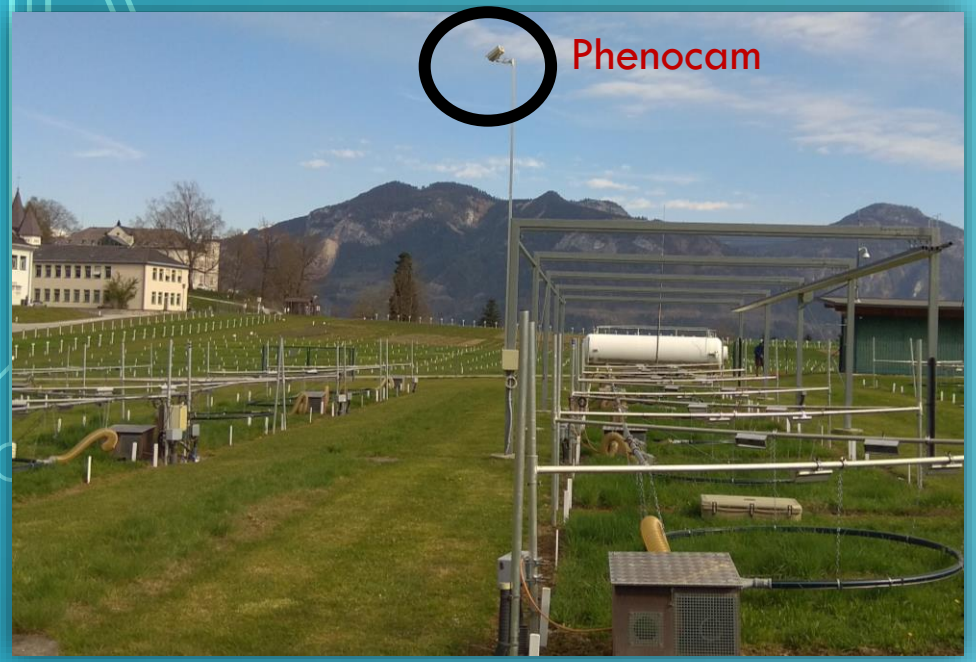
CT Elevated CO2 & elevated temperature (+300 ppm + 3°C)

CTD Elevated CO2, elevated temperature & Drought (+300 ppm + 3°C + rainout shelter during Jun to Jul)

Interactive Effects

METHODS

We use 3 methods to study the phenology in this experiment

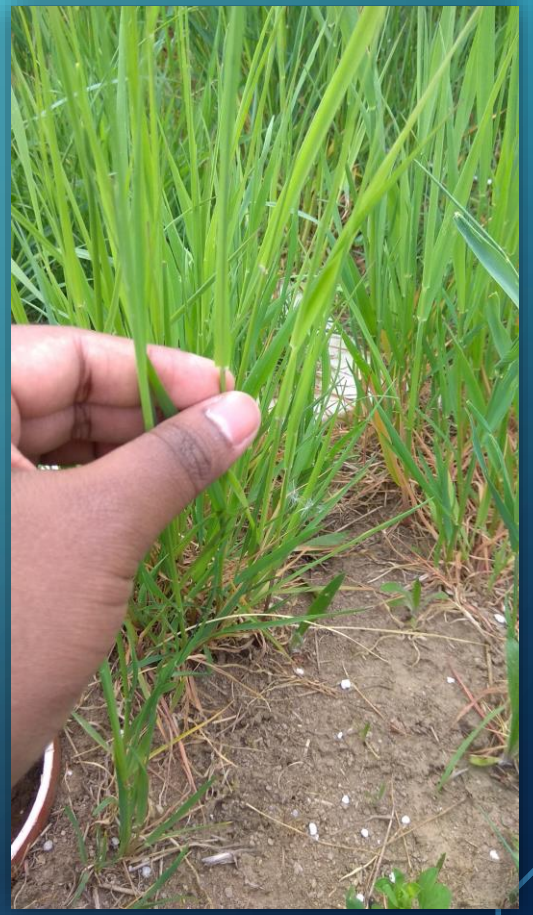


Phenocam images

Phenopix R program

Weekly Nadiral images

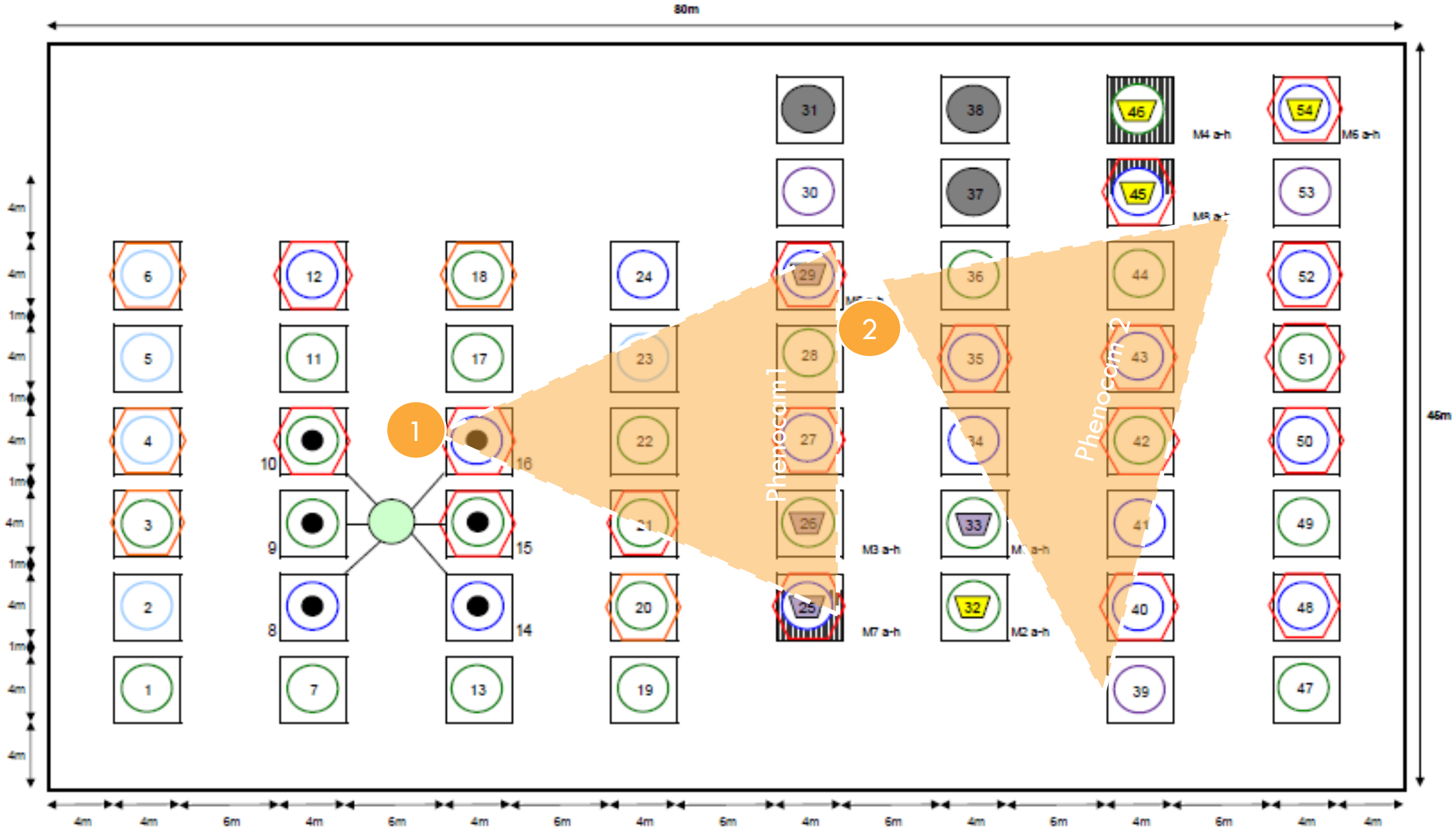
Phenopix R program



Weekly Ground Observations

BBCH Scale

Positions of Phenocams ClimGrass



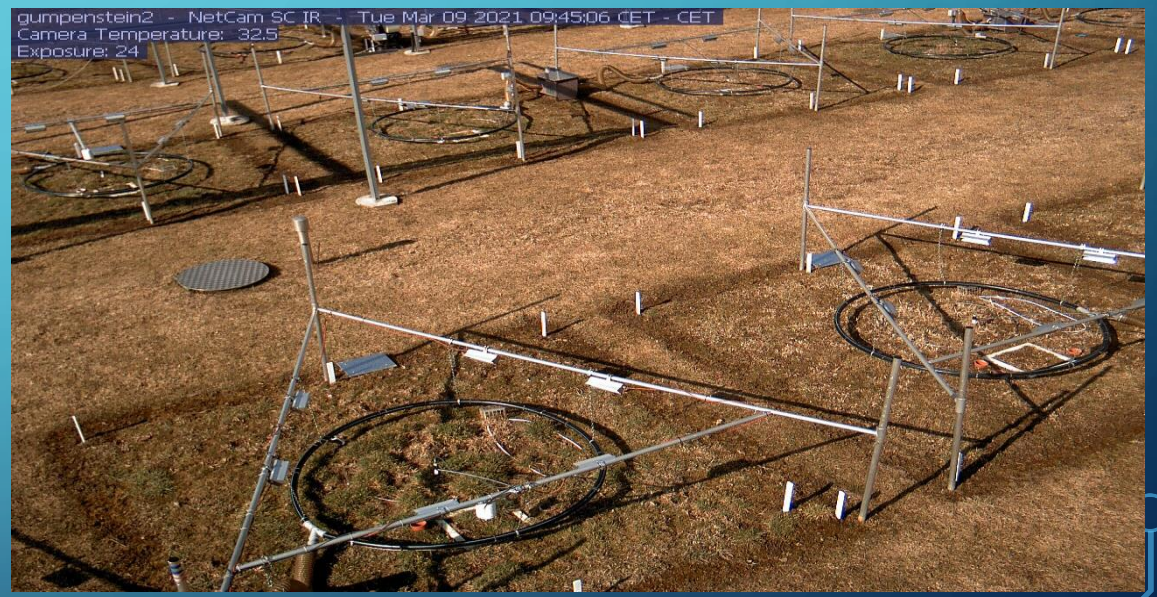
IN THIS PRESENTATION

- I present only the phenocam data…
- The phenocam images are analyzed using Phenopix R program.
- This package was designed for processing digital images of the vegetation cover in order to compute vegetation indexes that can be in turn used to track the seasonal development of the vegetation

Filippa, Gianluca. (2020). phenopix R package vignettes 1/3: base vignette.

PHENOCAM IMAGES
TWO PHENOCAMS ARE INSTALLED IN THE SITE AND THEY CAPTURE 5 IMAGES PER DAY.

Phenocam 1 image



Phenocam 2 image

PHENOCAM DATA ANALYSIS

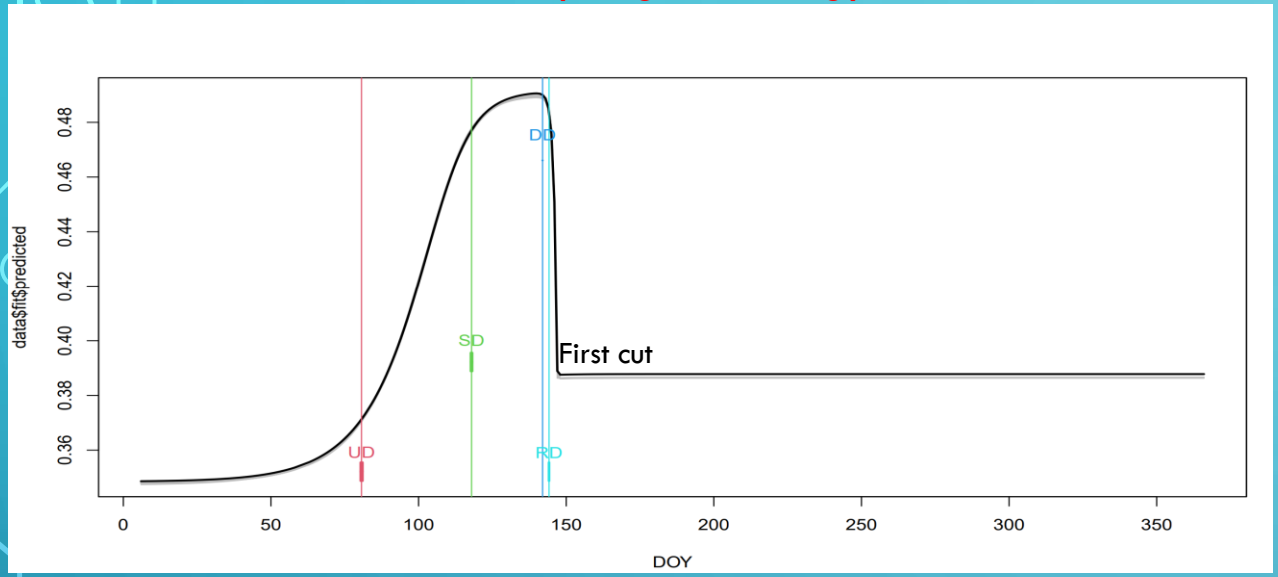
- The entire year's data is divided into four periods based on the grass cut days.
- GP1 – to observe spring phenology – Jan to May
- GP2 – to observe peak summer drought for the drought plots – Jun to July
- GP3 – to observe the recovery after the drought after rewetting the drought plots – Aug to Sep
- GP4 – after the 3 cut at the end of September till December

Note:

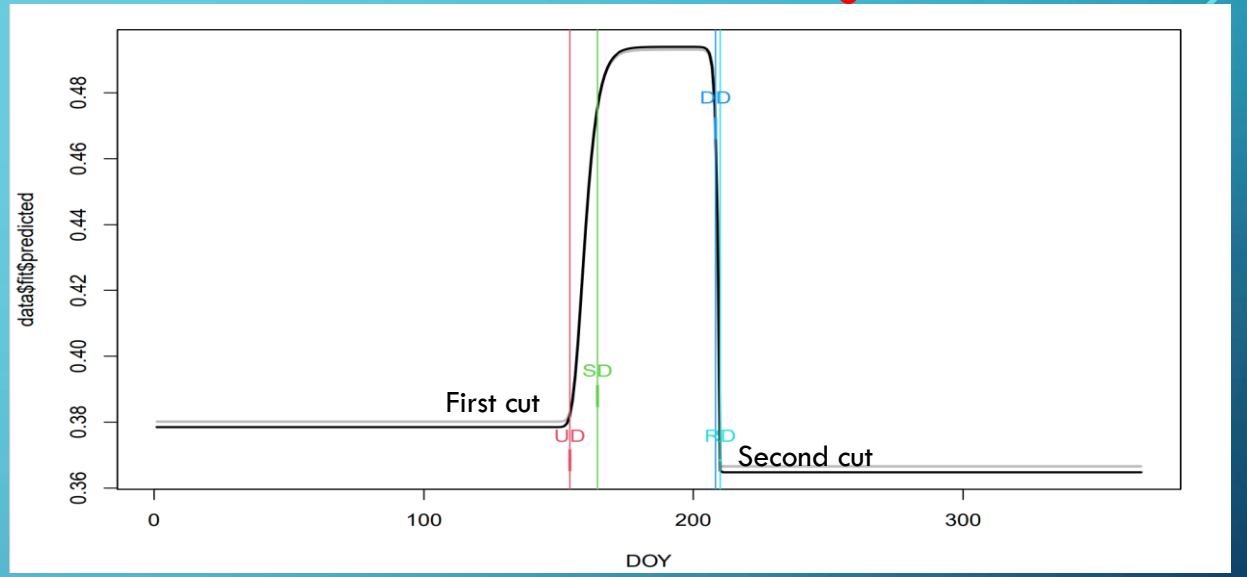
- First grass cut happens at the end of May
- Second cut – end of July
- Third cut – end of September
- Rewetting of the drought plots happen after the 2nd cut.

CREATING 4 GPs AND FITTING CURVES FOR THE FILTERED DATA

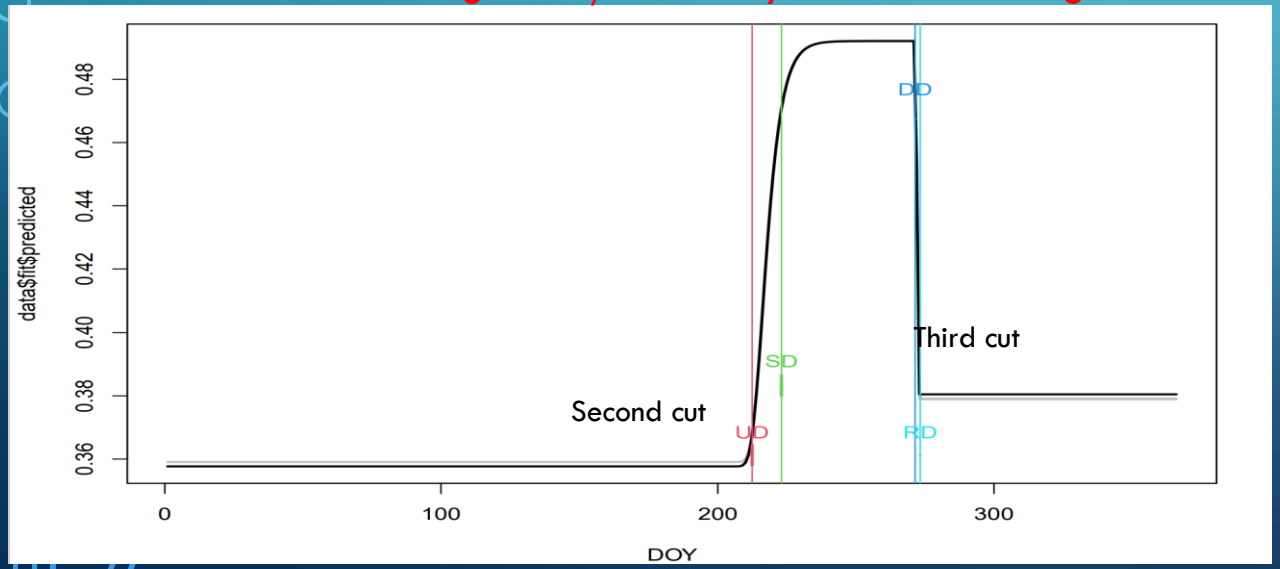
GP 1- Spring Phenology



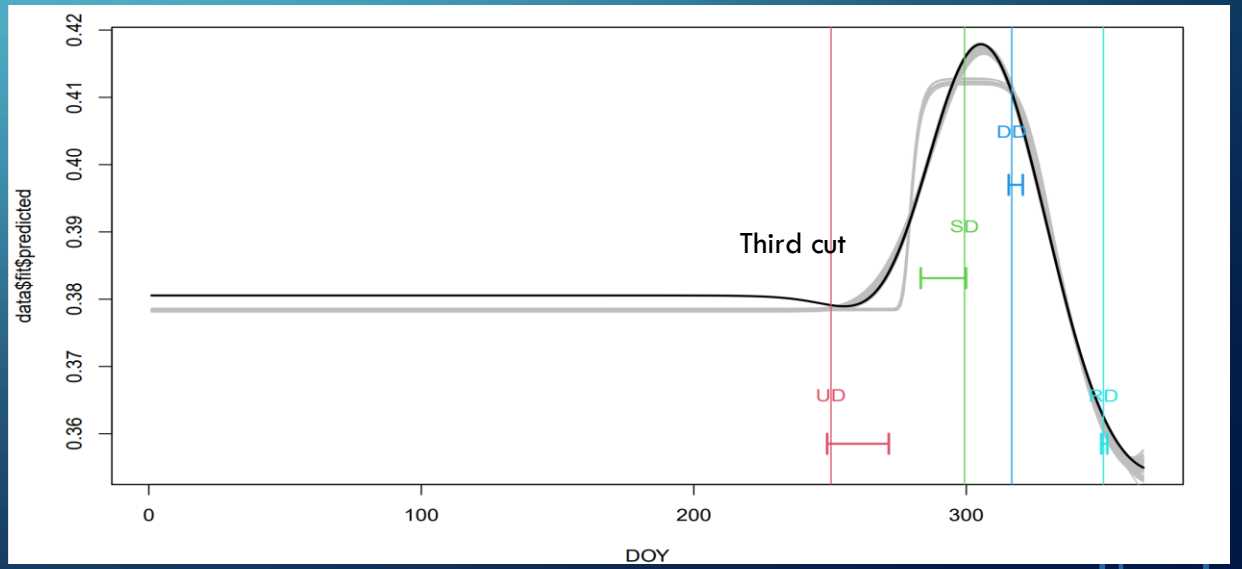
GP 2- Peak Summer Drought Period



GP 3- Regrowth/Recovery after rewetting



GP 4- After the 3 cut till end of December



RESULTS

- We can derive various useful metrics through phenopix program to study the phenological characteristics from the phenocam images.
- However, I choose only 3 metrics to explain my results in this presentation.

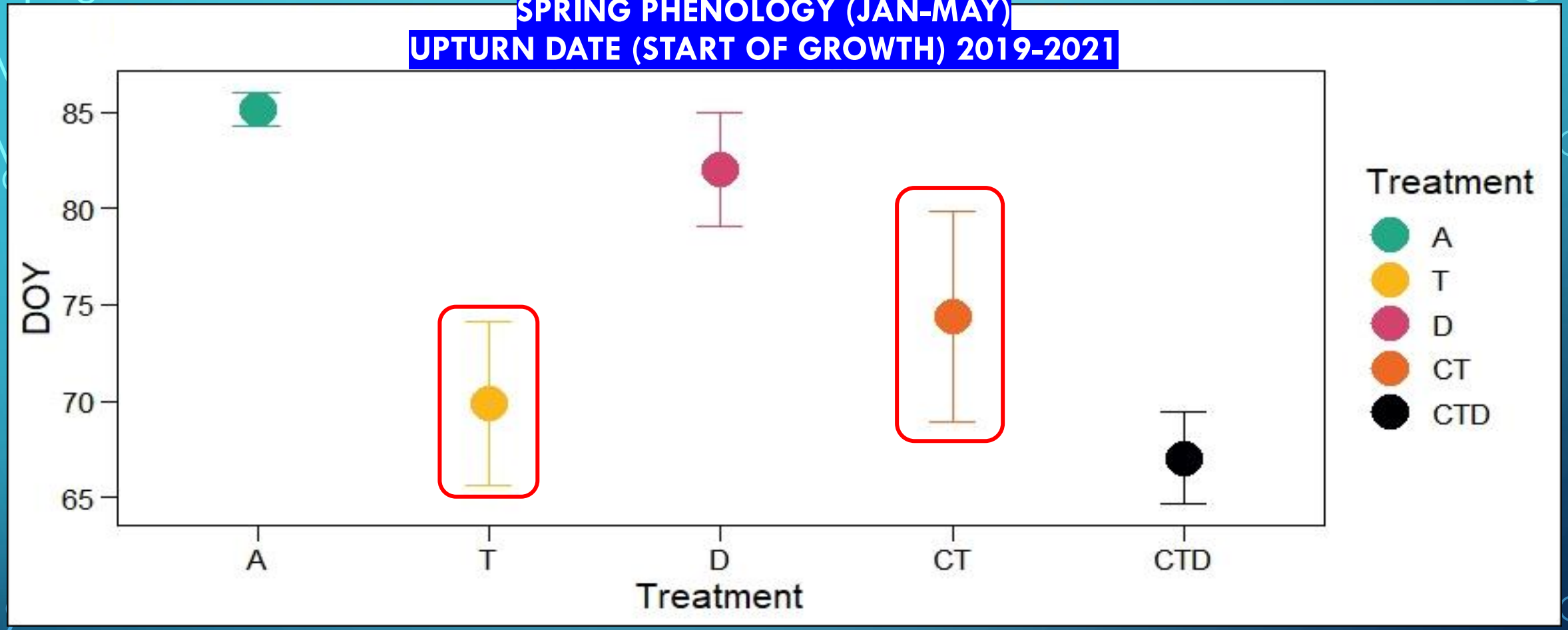
Metrics

1. UD- Upturn date – Start of growth
2. Peak growth – highest GCC value
3. Rate of growth – the speed which the plants grow measured as prr (Peak Recovery Rate)

If you are interested to know about other metrics, please contact me

PRELIMINARY RESULTS OF PHENOCAM DATA

SPRING PHENOLOGY (JAN-MAY)
UPTURN DATE (START OF GROWTH) 2019-2021



A -Ambient/Control

C -Individual elevated CO2

T -Individual Warming

D -Individual Drought

CT -Interactive – Elevated CO2 & Warming

CTD -Interactive- Elevated CO2, Warming & Drought

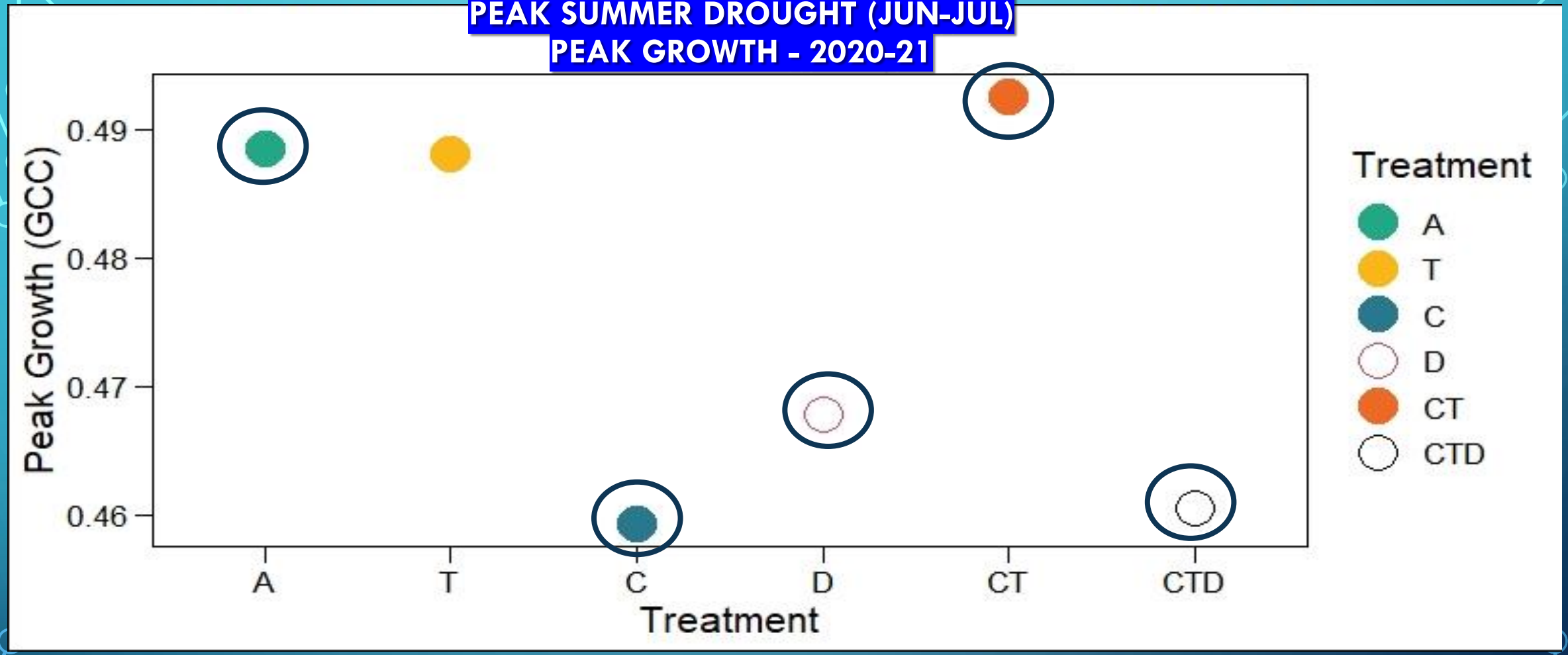
EXPLANATION OF THE RESULTS

- The upturn date (UD)/ start of growth date - average for the 3 years' data (2019-21) with error bars is plotted in the previous slide.
- It is clear that the individual elevated temperature at +3°C has earlier UD compared to other treatments.
- Please note CTD plot, though shows an early upturn date, acts as if CT because there is no drought conditions at this part of the year (Jan to May). There can also be drought legacy effects of previous year – which we need to study further.
- Here we focus only on the treatments A, T, and CT.

To know the Treatment codes, A, C, T, D, etc please refer to slide no 13

PRELIMINARY RESULTS OF PHENOCAM DATA

PEAK SUMMER DROUGHT (JUN-JUL)
PEAK GROWTH - 2020-21



A -Ambient/Control

C -Individual elevated CO2

T -Individual Warming

D -Individual Drought

CT -Interactive – Elevated CO2 & Warming

CTD -Interactive- Elevated CO2, Warming & Drought

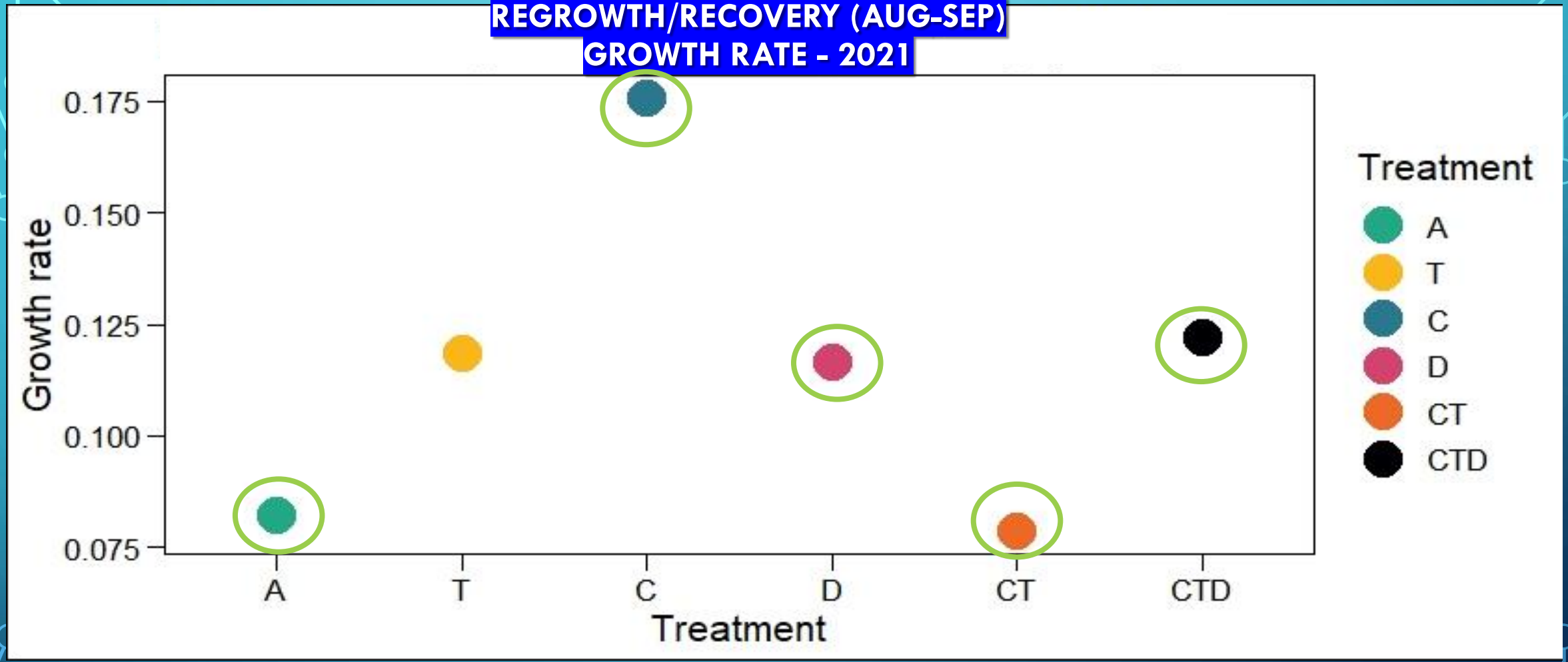
EXPLANATION OF THE RESULTS

- During the peak summer drought for the years 2020-21 we have plotted the Peak growth metric.
- We find a stunning lower peak growth of individual elevated CO2 at +300 ppm and a higher peak growth of CT treatment.
- What is of interest is during this drought period is that we observe a significant lower peak growth in both D and CTD plots indicating drought effect or impact.

To know the Treatment codes, A, C, T, D, etc please refer to slide no 13

PRELIMINARY RESULTS OF PHENOCAM DATA

REGROWTH/RECOVERY (AUG-SEP)
GROWTH RATE - 2021



A -Ambient/Control

C -Individual elevated CO2

T -Individual Warming

D -Individual Drought

CT -Interactive – Elevated CO2 & Warming

CTD -Interactive- Elevated CO2, Warming & Drought

EXPLANATION OF THE RESULTS

- In the results pertaining to GP3 – after rewetting during Aug to Sep, (rewetting is done after the drought period and the second cut), we find an interesting scenario of a higher growth rate in both D and CTD treatments.
- We also find another stunning scenario of lower growth rate in CT treatment and a highest growth rate in C treatment.

To know the Treatment codes, A, C, T, D, etc please refer to slide no 13

TAKE HOME MESSAGES

Conclusion

- **Warming advances** spring phenology both individually and in combination with CO2 – by **10** and **15 days** respectively.
- **Elevated CO2** drives **growth rate**.
- **Interactive effects** of +3˚C, +300ppm & drought **slow down growth rate** and reduce peak growth.

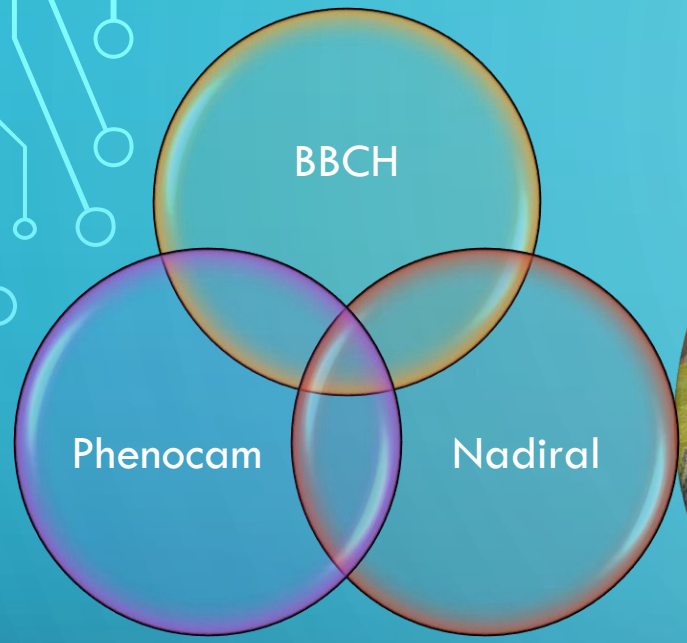
Interactive effects are stronger than individual effect

Temperature and drought are the key drivers

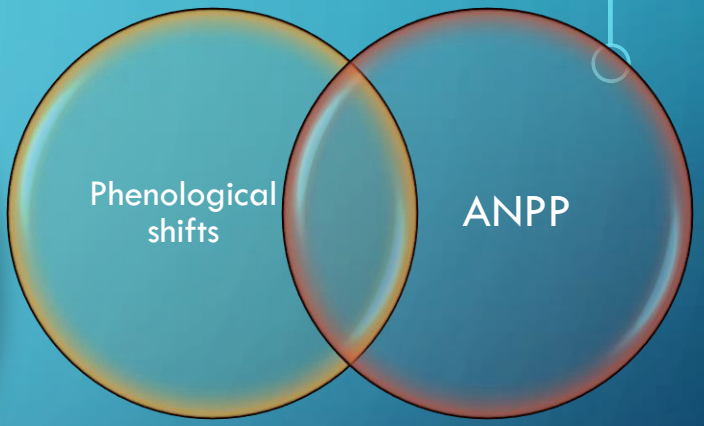
Individual CO2 shows stronger impact

PHENOLOGY

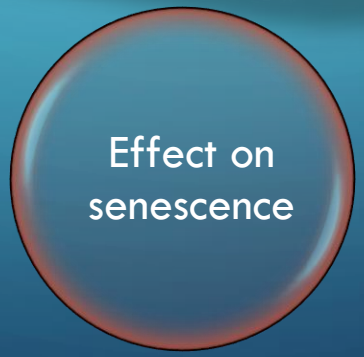
WAY FORWARD….



CORRELATING



ASSESSING



UNDERSTAND

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THANKS!

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FOR ANY QUESTIONS OR CLARIFICATION, PLEASE FEEL FREE TO CONTACT ME

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