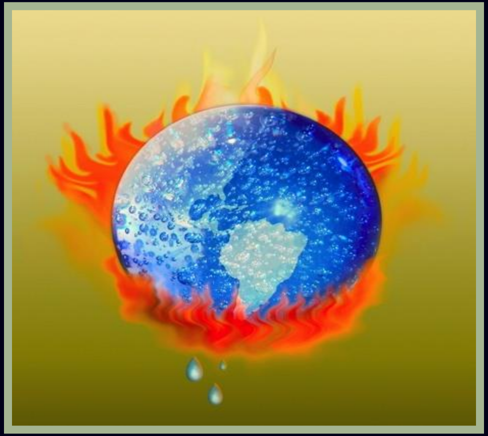
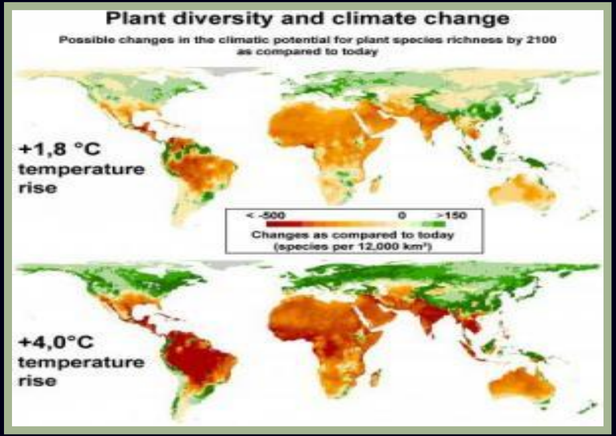
Impact of

Climate Change on Phytodiversity





Dr. K. SAMBANDAN

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Arignar Anna Govt Arts and Science College

Karaikal - 609 605

A Unique Planet

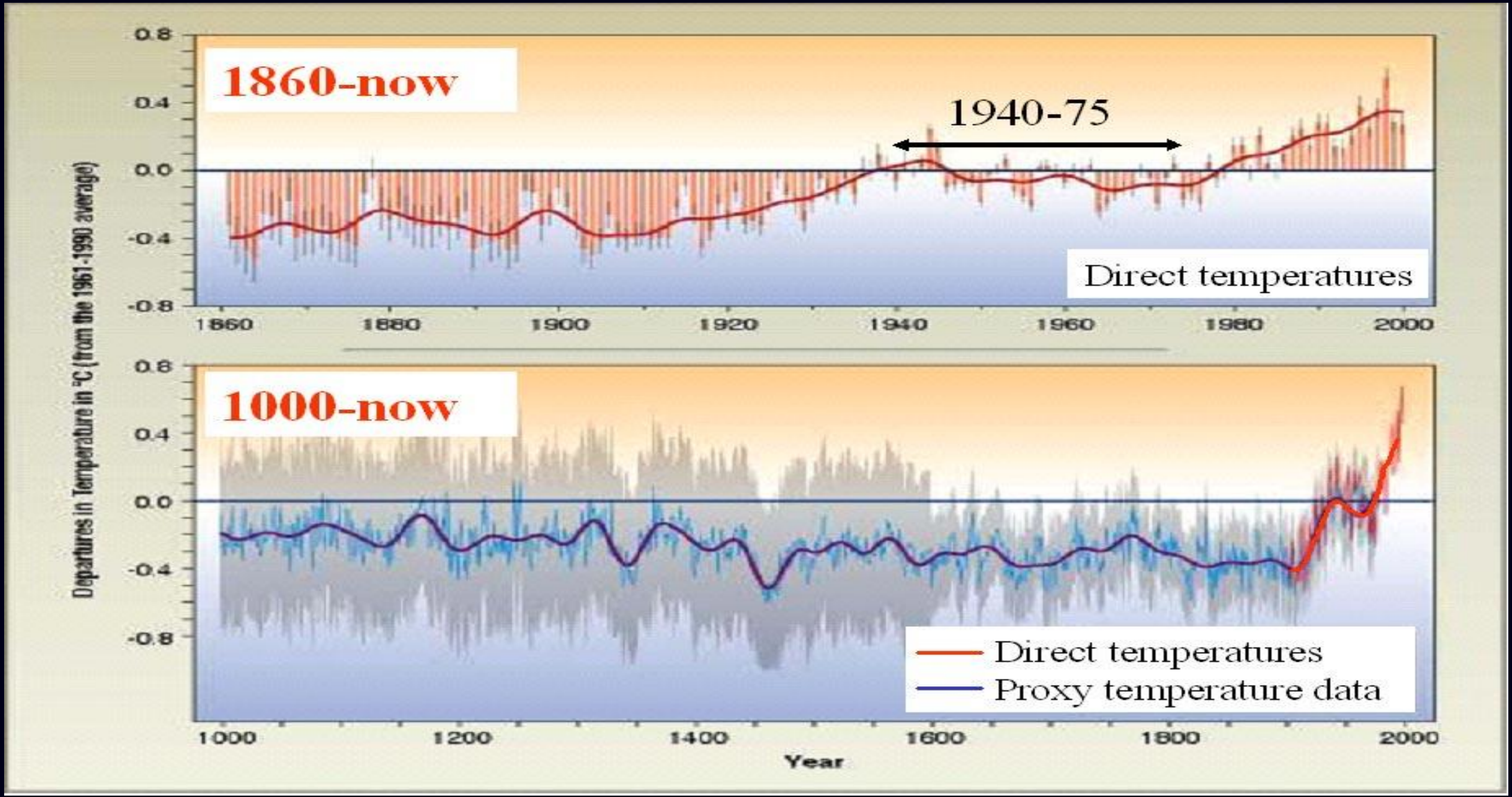
Earth's atmosphere is about 300 miles (480 kilometers) thick.

- Extensive continental structure.
- Plate tectonic activity and volcanism.
- Liquid water covering most of the surface.
- Oxygen-rich atmosphere.
- Relatively strong magnetic field.
- Supports life !!!

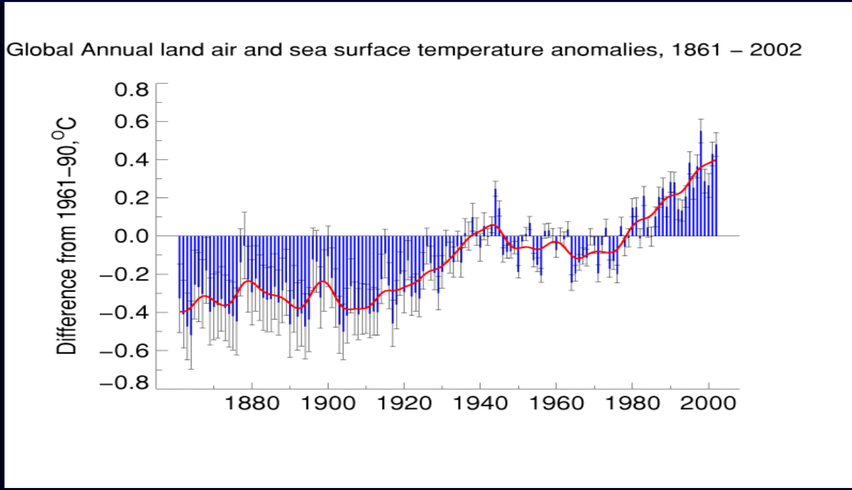
Climate: History

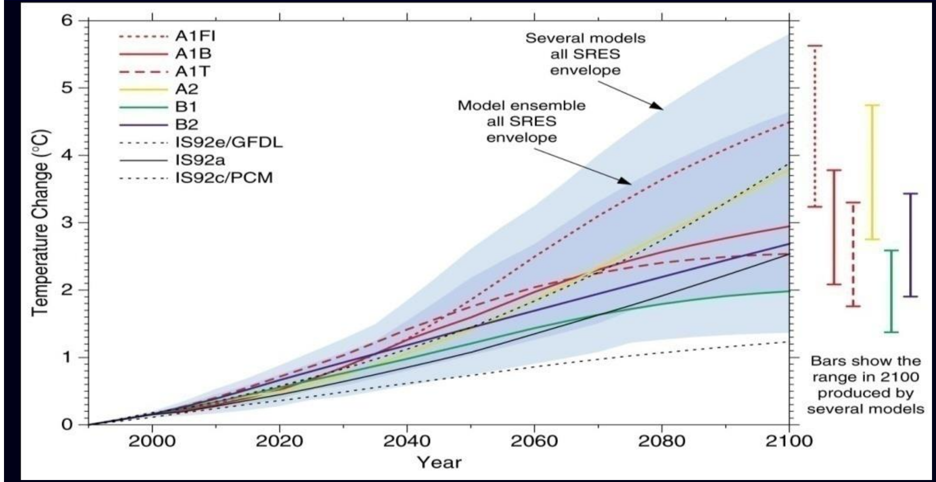
- Earth's climate has changed throughout history. Last 6,50,000 years there have been seven cycles of glacial advance and retreat, with the abrupt end of the last ice age about 11,700 years ago.
- End of Ice age was marked the beginning of the modern climate era — and of human civilization.
- Ice cores drawn from glaciers show that Earth's climate responds to changes in greenhouse gas levels of the past.
- Ancient evidences can also be found in tree rings, ocean sediments, coral reefs, and layers of sedimentary rocks.

Global average temperature (º C) over the past Millennium



Climate Change

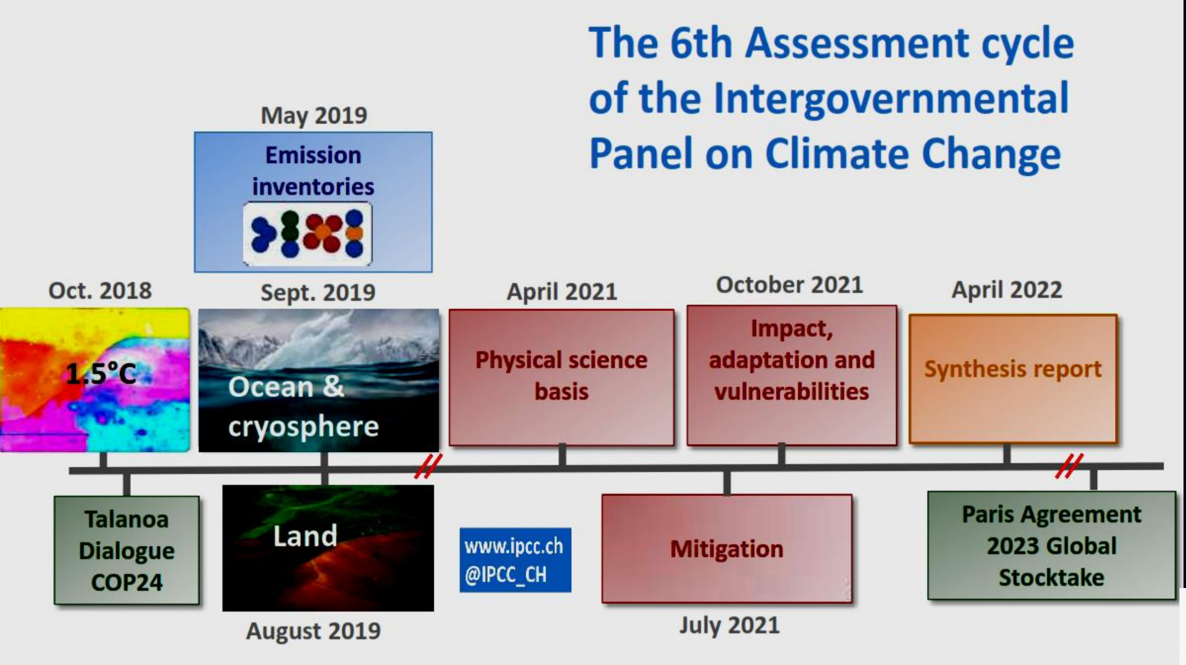




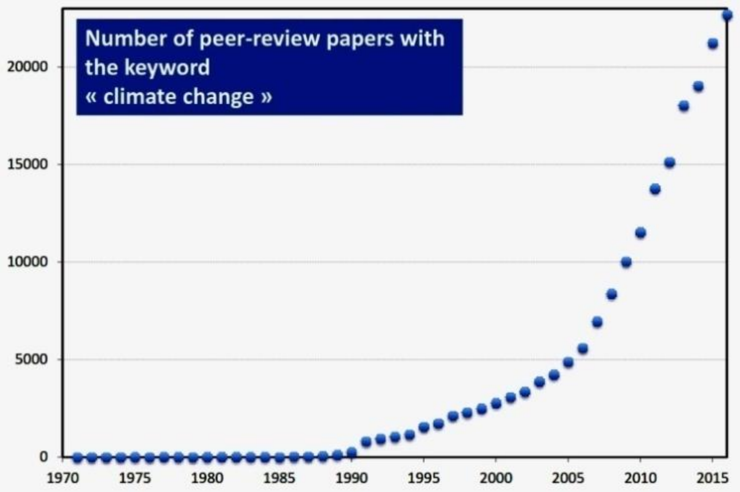
- **Over the 20th Century, the global average Surface Temperature has increased by 0.6 ± 0.2°C (IPCC, 2001) (Where most of the warming has occurred between 1976 and 2000).**
- **Further it is projected to increase by 1.5 to 2 °C over next few decades.**

Scientific evidence for warming of the climate system is unequivocal.

- Intergovernmental Panel on Climate Change

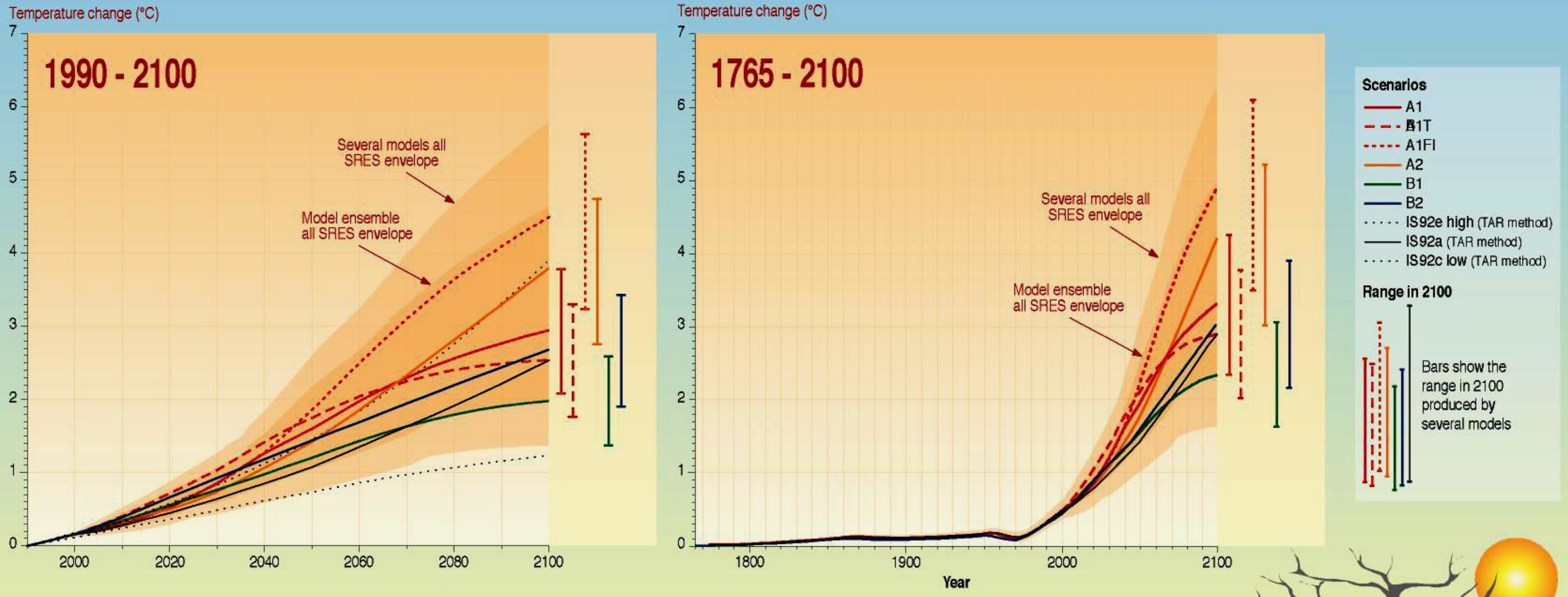


The 6th Assessment cycle of the Intergovernmental Panel on Climate Change
May 2019
Emission inventories
Oct. 2018
1.5°C
Sept. 2019
Ocean & cryosphere
April 2021
Physical science basis
October 2021
Impact, adaptation and vulnerabilities
April 2022
Synthesis report
Talanoa Dialogue COP24
Land
August 2019
www.ipcc.ch
@IPCC_CH
Mitigation
July 2021
Paris Agreement 2023 Global Stocktake

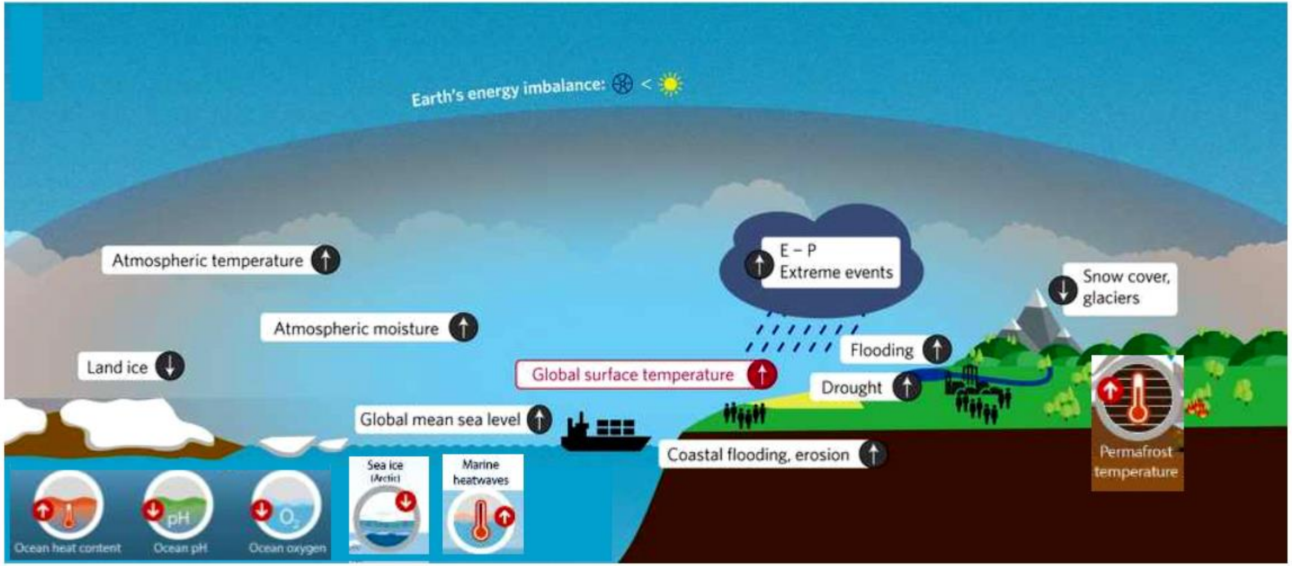


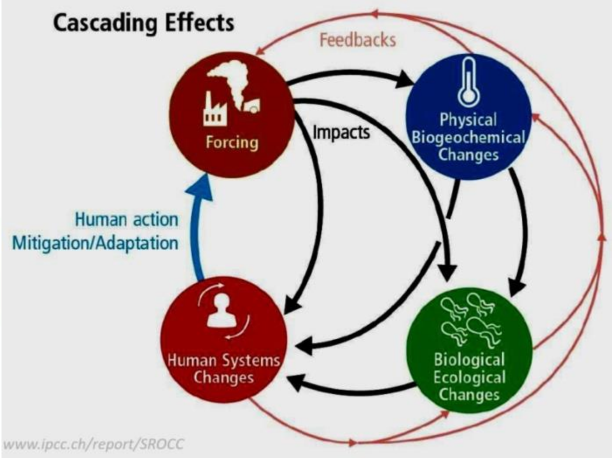
Number of peer-review papers with the keyword « climate change »
20000
15000
10000
5000
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

Temperature change (1760 - 2100)



Climate change hazards





- Weather reflects short-term conditions of the atmosphere.
- Weather can change from minute-to-minute up to season-to-season
- Climate is the long-term pattern of weather in an area, typically averaged over a period of 30 years.
- It include meteorological variables such as temperature, humidity, atmospheric pressure, wind, and precipitation.

Climate Change: Some Key Facts

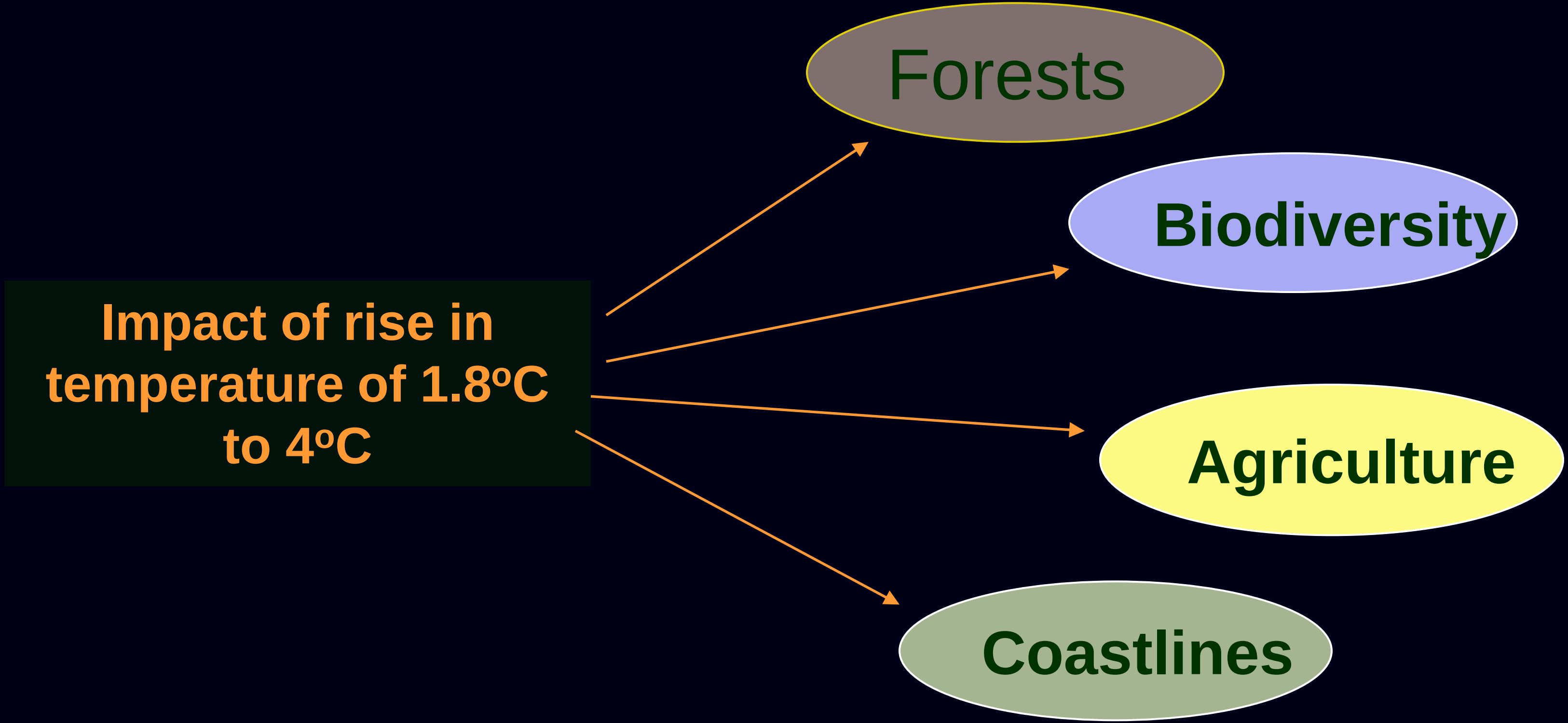
- Temperature increases have been greater in winter than in summer, and there is mainly by changes in minimum (nighttime low) temperatures (Kukla and Karl 1993).

- Changes in precipitation patterns have also been observed, but are more variable than those of temperature.

- Considering the temperature data, the northern hemisphere is warming more rapidly than the southern hemisphere (Foster and Rahmstorf, 2011)

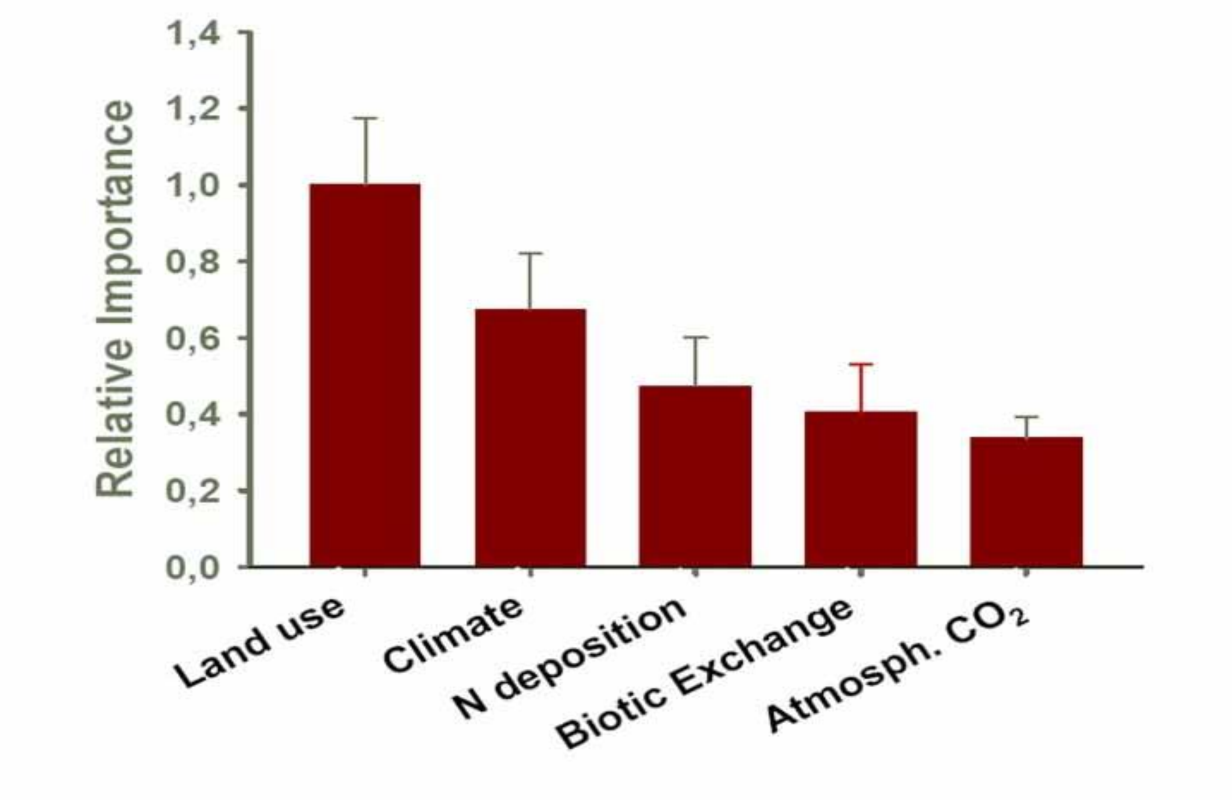
- Scientists predict that very huge number of species are on track for extinction in the coming decades.

Impacts of Climate Change

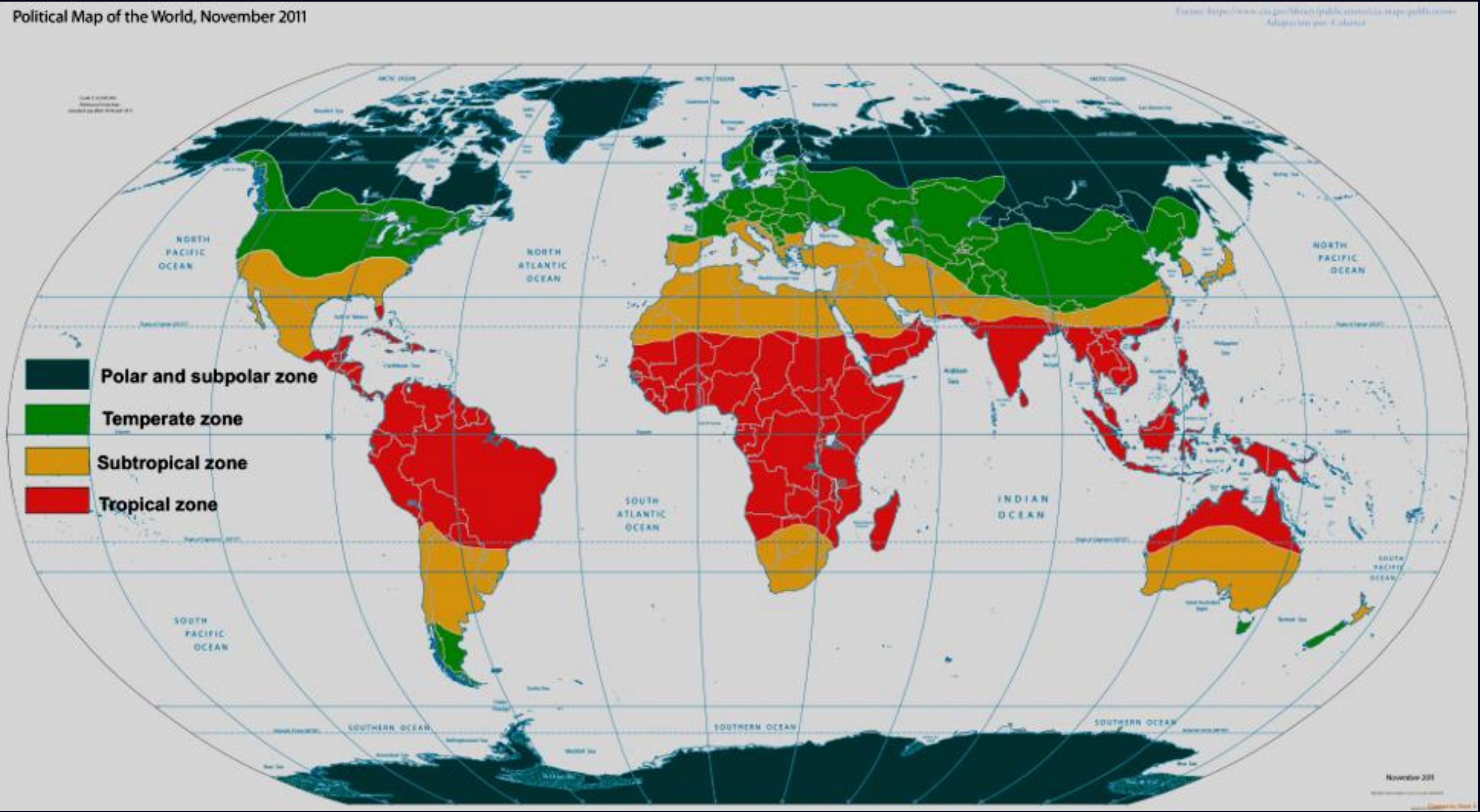


Climate change is one of the most devastating problems that humanity has ever faced and the clock is running out.

Major drivers of biodiversity change

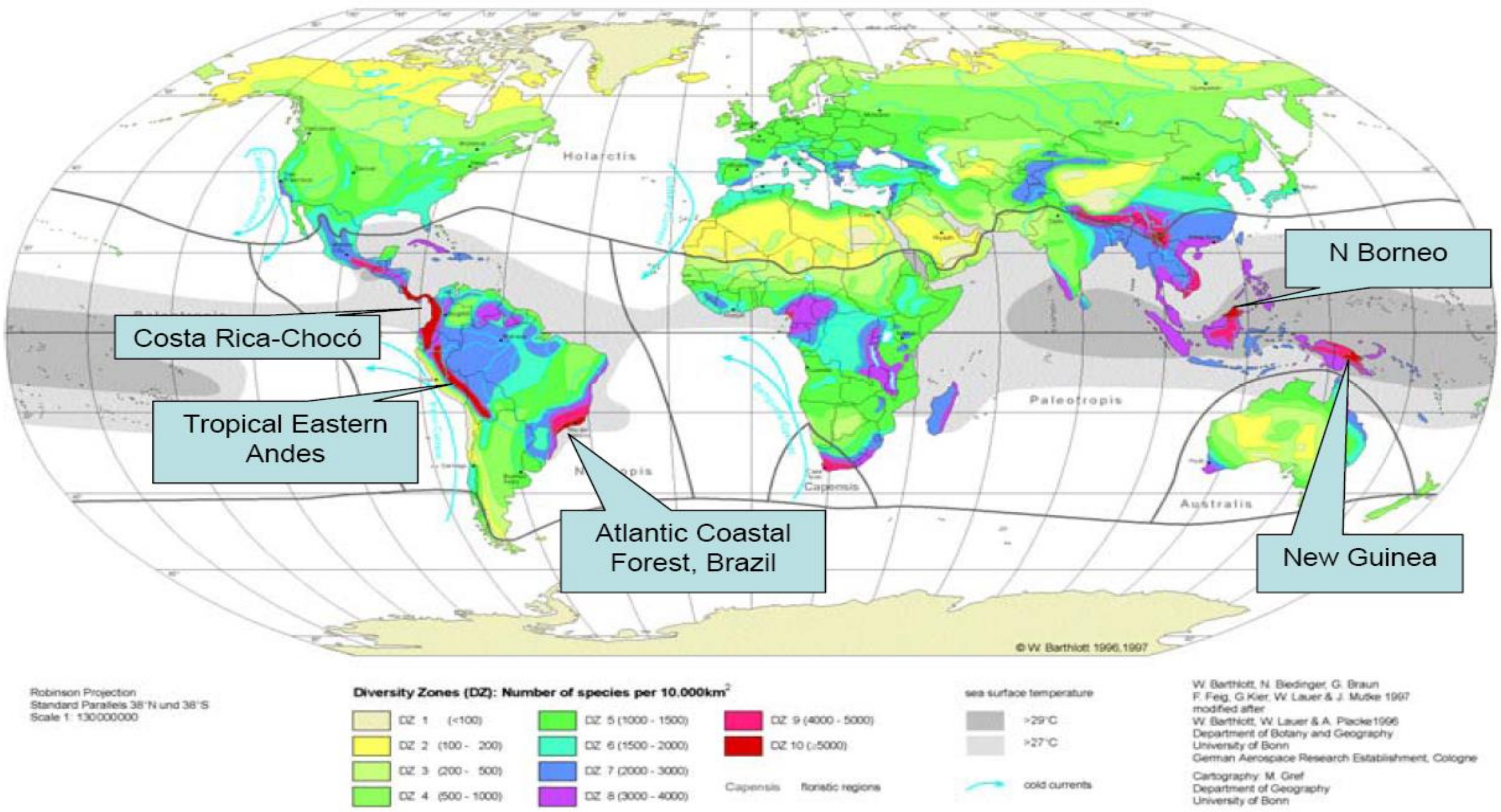


Saha *et al.* (2000) *Science* **287**:1770-1774



The Köppen climate classification is one of the most widely system divides climates into five main climate groups.

GLOBAL BIODIVERSITY: SPECIES NUMBERS OF VASCULAR PLANTS



Global Biodiversity: Species numbers of vascular plants

- The diversity of vascular plants is very unevenly distributed across the globe.
- The five centres that reach species richness of more than 5,000 spp./10,000 km2 (Costa Rica-Chocó, Atlantic Brazil, Tropical Eastern Andes, Northern Borneo, New Guinea) cover only 0.2 % of the terrestrial surface.
- On the other hand approximately 18,500 spp. are endemic to these centres which represent 6.2 % of all vascular plant species.
- Most of the global centres are located in mountainous regions within the humid tropics, which provides suitable climatic conditions.

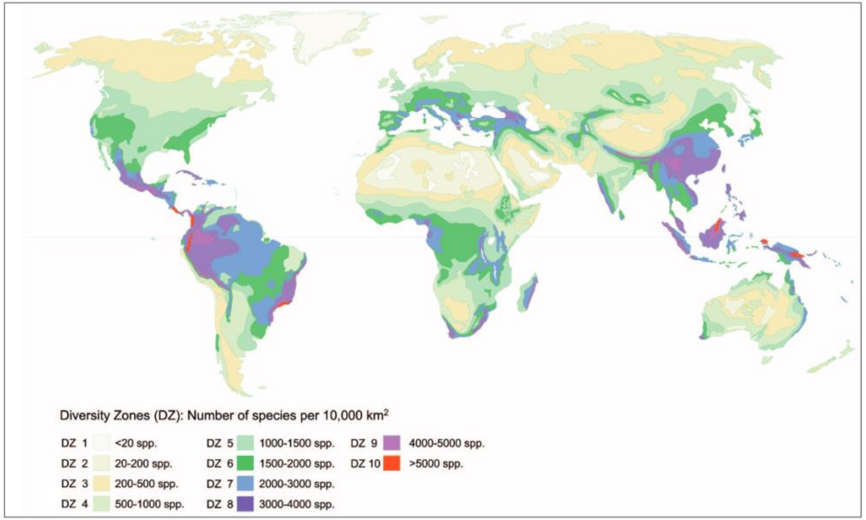
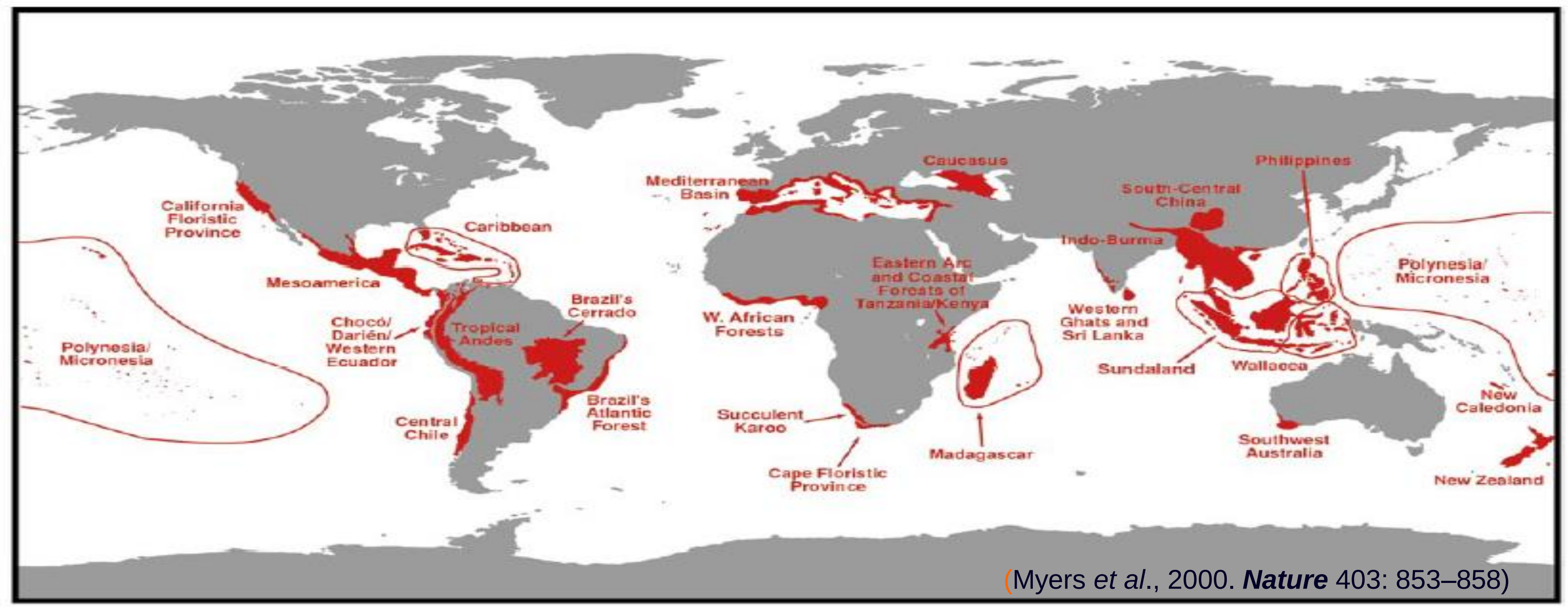


Fig. 1 Global Biodiversity: Species numbers of vascular plants. W. Barthlott, G. Kier, H. Kreft, W. Küper, D. Rafiqpoor and J. Mutke 2005 revised after Barthlott et al. 1996, Nees Institute for Biodiversity of Plants, University of Bonn. Robinson Projection, Standard Parallels 38 °N and 38 °S

Biodiversity Hotspots



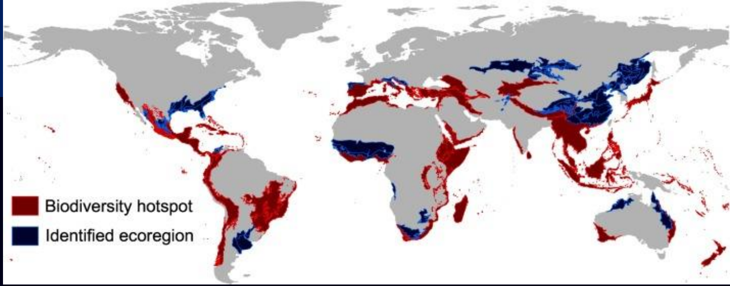
(Myers *et al*., 2000. ***Nature*** 403: 853–858)

There are 36 biodiversity hotspots on our planet.

Earth's Biologically Richest and Most Endangered Terrestrial Eco-regions.

Biodiversity Hotspots

- A biogeographic region with significant levels of biodiversity that is threatened by human habitation.
- It must contain at least 0.5% or 1,500 species of vascular plants as endemics, and it has to have lost at least 70% of its primary vegetation.
- Hotspots support nearly 60% of the world's plant, bird, mammal, reptile, and amphibian species, with a very high share of those species as endemics.
- Some of these hotspots support up to 15,000 endemic plant species and some have lost up to 95% of their natural habitat.
- The original 25 hotspots covered 11.8% of the land surface area of the Earth.



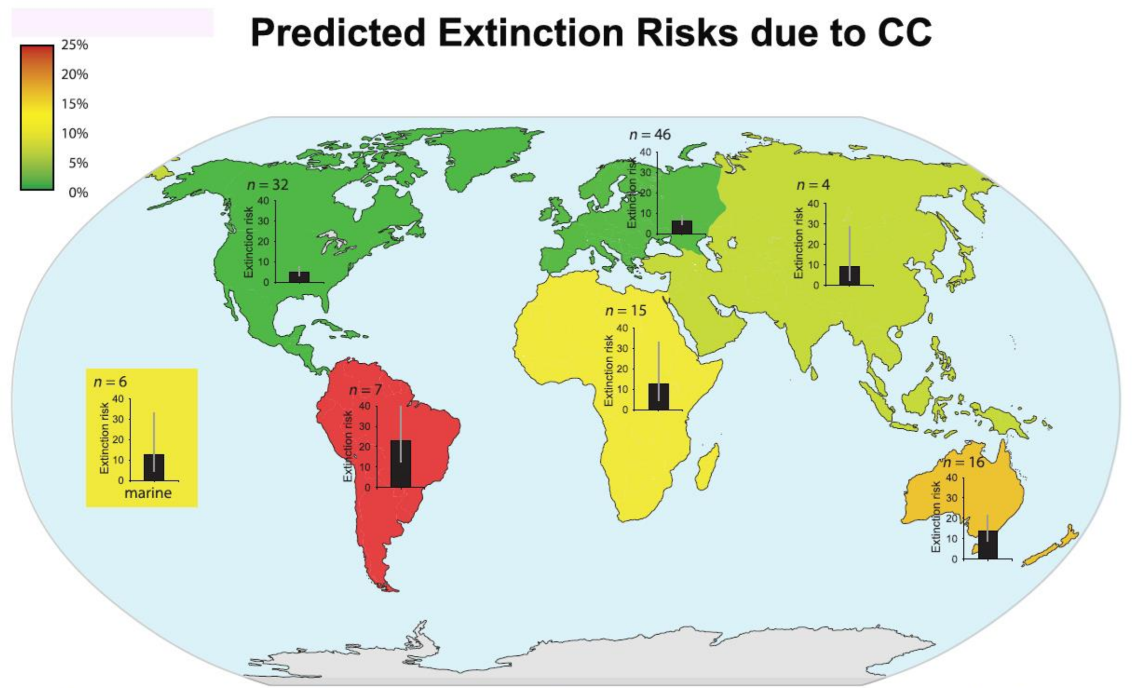
Yuta Kobayashi *et al.*, 2019. ***Biological Conservation* 233:**268-275

Extinction risks and Climate Change

Current predictions of extinction risks due to climate change vary widely depending on the specific assumptions and geographic focus.

Results suggest that extinction risks will accelerate with future global temperatures, <u>threatening up to one in six species</u> under current policies.

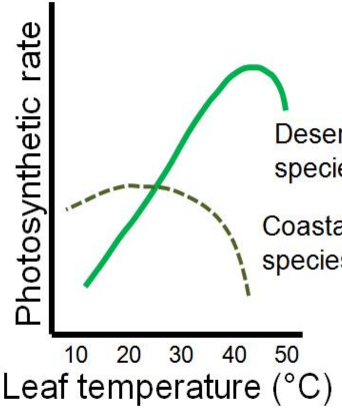
Extinction risks were highest in South America, Australia, and New Zealand, and risks did not vary by taxonomic group.



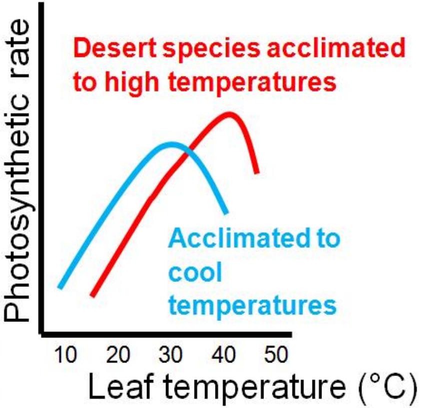
Predicted extinction risks from climate change differ by region. The highest risks characterized South America, Australia, and New Zealand (14 to 23%), and the lowest risks characterized North America and Europe (5 to 6%). Colors indicate relative risk. Bar graphs with 95% CIs and number of studies (*n*) are displayed.

572 1 MAY 2015 • VOL 348 ISSUE 6234 sciencemag.org SCIENCE

Plants can adapt and acclimate to temperature extremes



Some plants have evolved to tolerate high temperatures



Larrea tridentata, an extremely thermotolerant desert plant

To a certain extent, most plants can acclimate to higher or lower temperatures, by sensing and responding to a change in temperature

Adapted from Berry, J., and Björkman, O. (1980). Photosynthetic response and adaptation to temperature in higher plants. Annu. Rev. Plant Physiol. 31: 491 – 543. Photo credit Sue in Az

- ***Ivesia bailey*** (Rosaceae) is adapted to living in extremely dry conditions Nevada Desert.
- This lifestyle is believed to have evolved in the genus *Potentilla* around 20 million years ago..

Impacts of Climate Change on the Flora

- Phenological Changes
- Changes in Distribution and Migration Range
- Change of Biotic Interactions (Competition, Pollination, Herbivory…)
- Changes in Species Composition
- Changes in Vegetation

Phenological Changes

- Phenology is the study of timing of periodic of biological events and their relationships with the environment.
- In temperate zones, the reproductive cycle of plants is controlled by Temperature, Day length, Rainfall, etc.
- Spring events such as Budding, leafing and flowering is regulated by temperatures.
- Phenophases are directly impacted by the local weather and climate, responding to environmental changes such as variations in temperature and precipitation.
- Changes in plant phenological patterns have been associated with the species specific plant structural architecture, availability and transfer of nutrients, plant growth rates, temperature and water .

Leaf unfolding

Beginning of flowering

General flowering

First ripe fruits

Autumn coloring

Leaf fall

Impacts of Climate Change

Phenological Changes

- Phenological observations are highly useful to assess ecological response to climate change.
- Phenological datasets to evaluate spatial and temporal impacts of climate on vegetation.
- Phenology has shown to address the questions in global modelling, monitoring and impact assessments of climate change .
- In total, Phenology are considered to be most sensitive and reliable indicator of climate change.

Techniques to access growing seasons in relation to climate change are

1. Phenology
2. NDVI Index
3. Surface air Temperature

Flowering Time

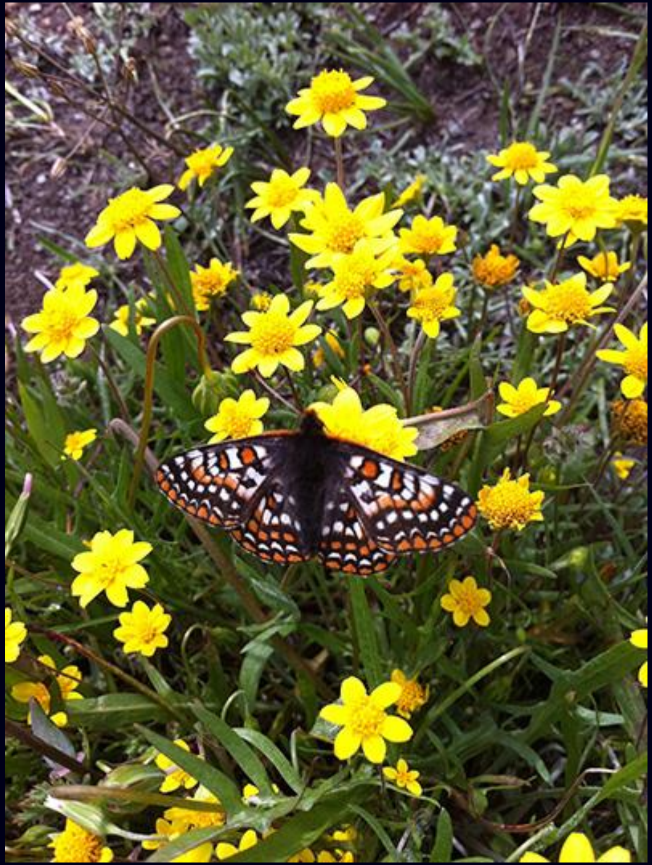
The flowering time is one of the most important events for plants.

It affects their chances of pollination, especially when the pollinator is itself seasonal, and determines the timing of seed ripening and dispersal.

Flowering time also influences insects for which pollen, nectar, and seeds are important resources for survival.

An earlier flowering time also entails an earlier activity in other processes such as leaf expansion, root growth, nutrient uptake etc., that are important for niche differentiation among coexisting species.

It also can alter competitive interactions between species. Therefore, large changes in flowering date may disrupt ecosystem structure.



Cherry blossom season in Japan

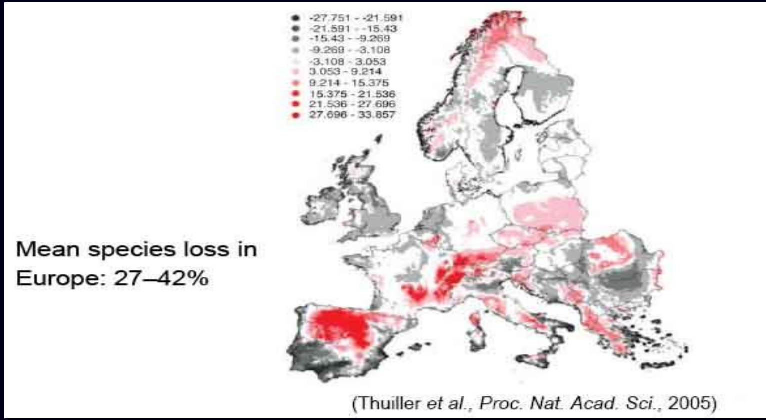
- Cherry blossom season in Japan is an annual spectacle that signals spring. Cherry blossoms in Japan usually peak in April, every year.

- In 2021, cherry blossoms peaked on March 26, which hasn’t occurred since 812 AD.

- Cherry blooms are very temperature sensitive, flowering and full bloom could be earlier or later depending on the temperature alone (Japan Meteorological Agency).

Phenological Changes in <u>Europe</u>

- Phenological time series data (last 132 years) from eight common plants at three different observational points in Estonia.
- Results of the study explained that Estonian spring advanced 8 days on average of eighty years period.
- It also explains that spring season was advancing two times more rapidly in coastal regions than inlands.



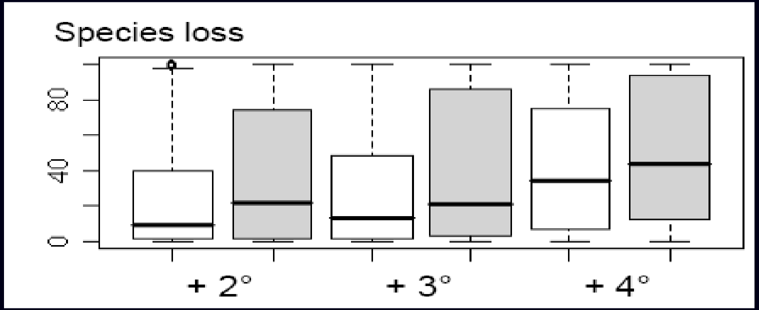
Impact of climate change on plant species richness In Europe

Ahas, 1999. *Int.J.Biometerol*. **42**: 119-123

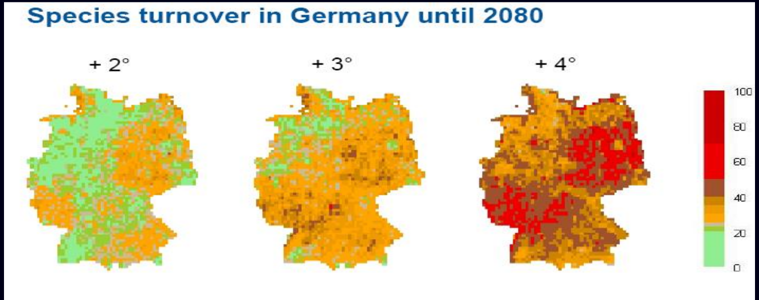
Impacts of Climate Change

Phenological Changes in Europe

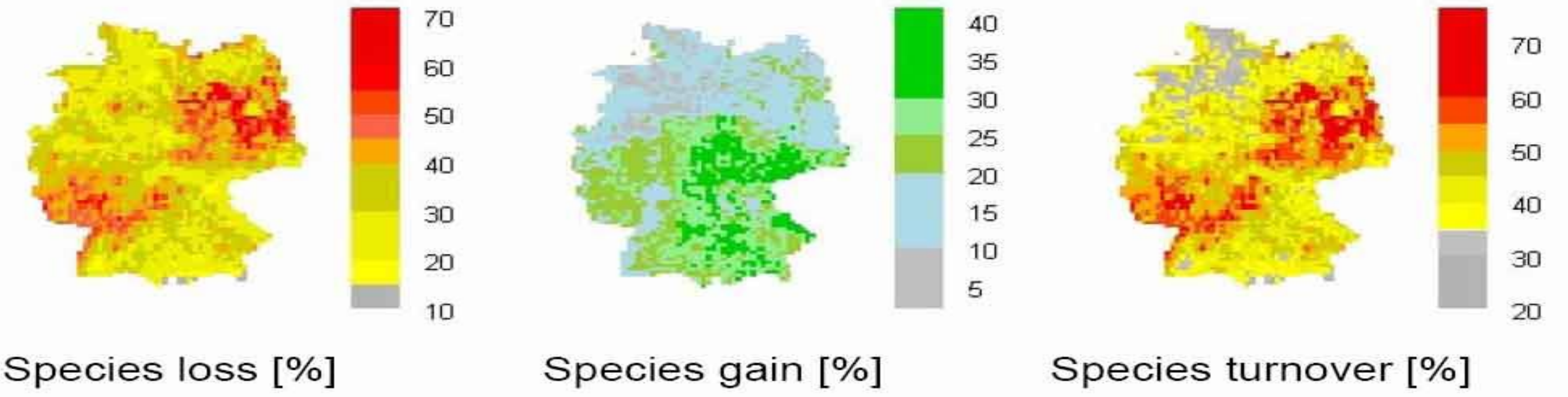
- In Germany (1951-1996), notable advances in the spring phenophases such as leaf unfolding of the deciduous trees (-0.16 days /Yr) but phenological changes are less strong in Autumn.
- Growing season has been lengthened by 0.2 days/Yr
- 1974-1996 period indicates higher phenological changes than 1951-1973 period



Impact of Red List species (Grey) in Germany.



Impact of Climate change on German Flora

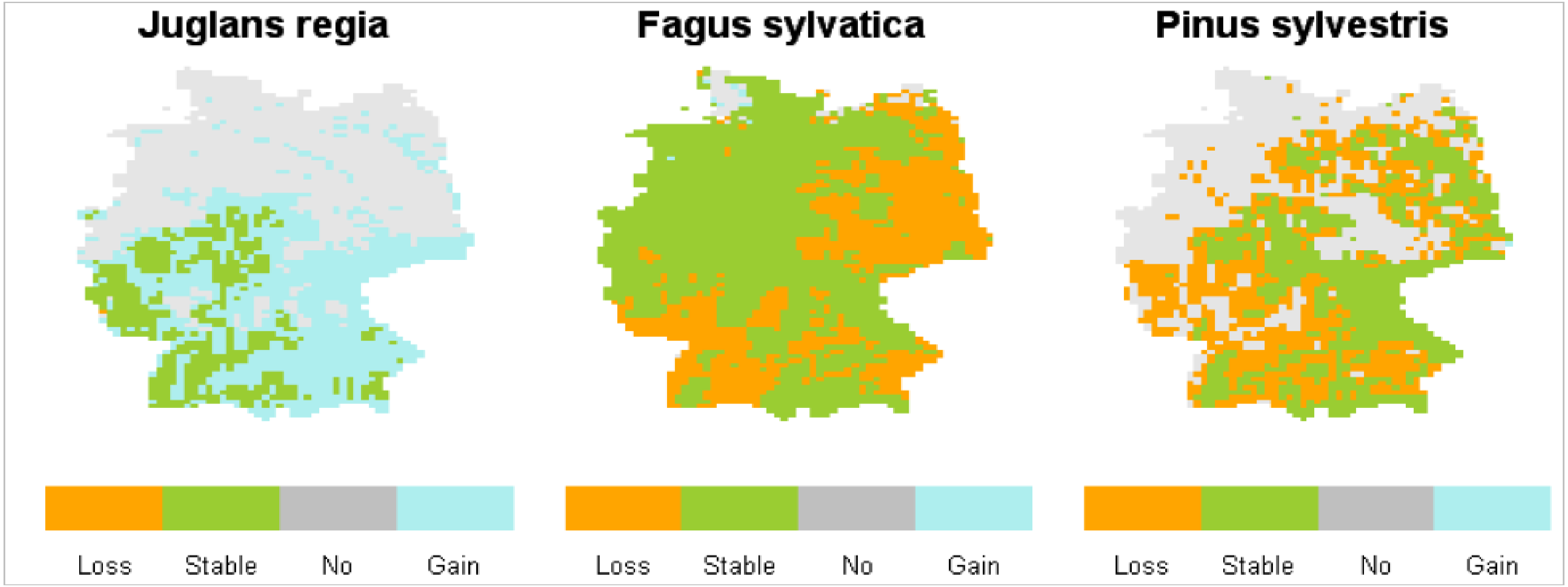


Modelled scenario 2080, +4°C
→ n= 845 species
→ 2995 grid cells (FLORKART).

Pompe, Badeck, Hanspach, Klotz,
Thuiller & Kühn, 2008, *Biology Letters 4, 564–567*

Species ranges are not static. Recent climate warming has resulted in species' ranges shifting polewards or to higher altitudes and is recognized as a major threat to biodiversity (Parmesan 2006).

+4°C distribution scenarios 2080



Impacts of Climate Change
Phenological Changes in Europe

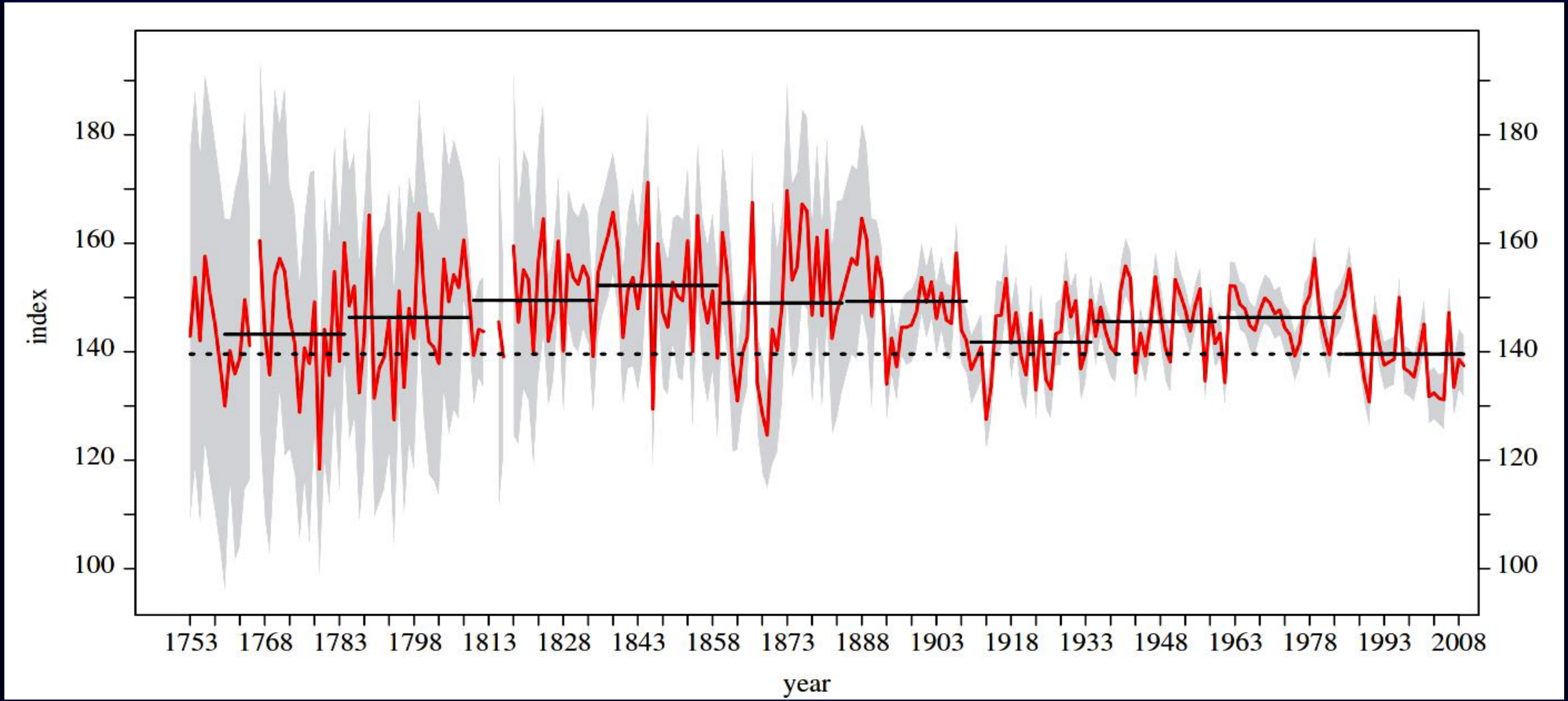
- First flowering date (FFD) is sensitive to Temperature.
- Average FFD 385 British plant species was recorded from 1980 to 2000.
- In terms of FFD, 80 % of the plants have advanced by 4.5 days where as another 15 % by 15 days.

Fitter & Fitter, 2002. *Science* **296**: 1689-91

Rubus chamaemorus
(Rosaceae)
(cloudberry)

Early flowering in both warming and snow conditions

Index of First Flowering Dates



- The median (red line) of the estimated community-level index (day of the year) showing a temporal change in the timing of first flowering by 405 plant species observed throughout the UK.
- The black line indicates the mean for every 25 years and the dotted line that for the most recent 25 years.

(T. Amano et al. 2015. Proc. R. Soc. B (2010) 277, 2451–2457. doi:10.1098/rspb.2010.0291)

Plant indicators of climate change in Ireland

Arctic/alpine plants such as

Dryas octopetala,

Alchemilla alpina

Salix herbacea

Currently have very restricted distribution patterns due to increase in temperature.

It might be expected that their distribution and range would become further reduced.

Alison Donnelly *et al.*, Int J Biometeorol (2004) 49:1–12

Plant indicators of climate change in Ireland

Mediterranean species, such as Euphorbia hyberna, Rubia peregrina and Saxifraga spathularis may extend their range in a north-east direction across Ireland as temperature increases .

Alison Donnelly *et al.*, Int J Biometeorol (2004) 49:1–12

Impacts of Climate Change

Phenological Changes in North America

- 55 phenophases were studied in South Wisconsin. One third of phenophase appeared to advance in earliness over the period (-0.12 days/Yr) in early spring.

- FFD of 100 plants from Washington DC showed that significant advance of 2.4 days over 30 years in 89 plant species. Remaining 11 plants exhibited late flowering.

Impacts of Climate Change

Phenological Changes in North America

- Wolfe et al (2005) evaluated first leaf date and FFD of woody plants (Lilac, Apple, Grape) for the period 1965-2001 in the North Eastern parts of USA.
- North Eastern USA had resulted in an advance in Spring phenology ranging from 2 to 8 days.

Apple tree in full bloom

Platanthera leucophaea
a rare and threatened species of orchid native to North America

Impacts of Climate Change

Phenological Changes in Asia

- 26 stations in Chinese phenology observation network for last 40 years of experiments showed that phenophase advance or delay to temperature change was non-linear.
- Rate of phenophase difference decreased with latitude.
- In South Korea, 5 tree species were studied for the period of 1922-2004. All 5 species showed an advance in spring bloom (-1.4 to 2.4 days/decade).
- 0.5 day/Decade associated with a 2 C warming over the 83 years

Imperata cylindrica (Poaceae)

Naive of East Africa,
Now in all Asian countries

Prunus davidiana

(Rosaceae)

Flowers are damaged by cold temperatures in late winter / early spring

In China

- First Bloom in spring was advanced Since 1985
- Lengthening the growing season was deducted from 1982 to 1993

Syringa oblata
Oleaceae

In China

- First Bloom in spring was advanced Since 1985
- Lengthening the growing season was deducted from 1982 to 1993

Robinia pseudoacacia

Fabaceae

In China

- **First Bloom in spring was advanced Since 1985**
- **Lengthening the growing season was deducted from 1982 to 1993**
- **5-10 days early flowering = 0.7 – 1 ^{o}C**

Hypericum perforatum

(St John's wort) *Hypericaceae*

- CC pushed towards cold regions
- Reduced capsule success
- Differential flower abortion
- Less abundant in UK

Tilia cordata (*Malvaceae*)

- Planted in Ireland to study the relationship between climate and Phenology.
- It shows positive correlation between LGS and annual average Temp. in all the sites.
- If spring Temp increases by 1°C, BGS will start 6 days earlier.

Cryptostegia grandiflora
(Asclepiadaceae)

- Introduced in Australia prior to 1875 as a garden ornamental in North Queen’s land. The plant Spread rapidly by early 1900s.

- Now it attained prominent weed status due to ability to form dense mono-specific strands, especially in riparian habitats

- It contains glycosides with toxic effects on cardiac systems. It fails to control chemically and biologically.

- Climatic models show that it will invade other areas when temp increases.

Garcinia indica (Thouars) Choisy

- Garcinia indica, a plant of the Clusiaceae family (also known mangosteen) is a fruit-bearing species that has cultural, pharmaceutical, culinary, and industrial significance.
- The species is also listed as a vulnerable species on The International Union for Conservation of Nature (IUCN) red list.
- it cultivates in regions where the dry season will be less than four month.
- The tree requires 20ºC to 36ºC temperature, 250-400 cm annual rainfall, and 70% humidity for its optimal growth.

Pramanik, M et al., (2017). Climate Risk Management
doi: https://doi.org/10.1016/j.crm.2017.11.002

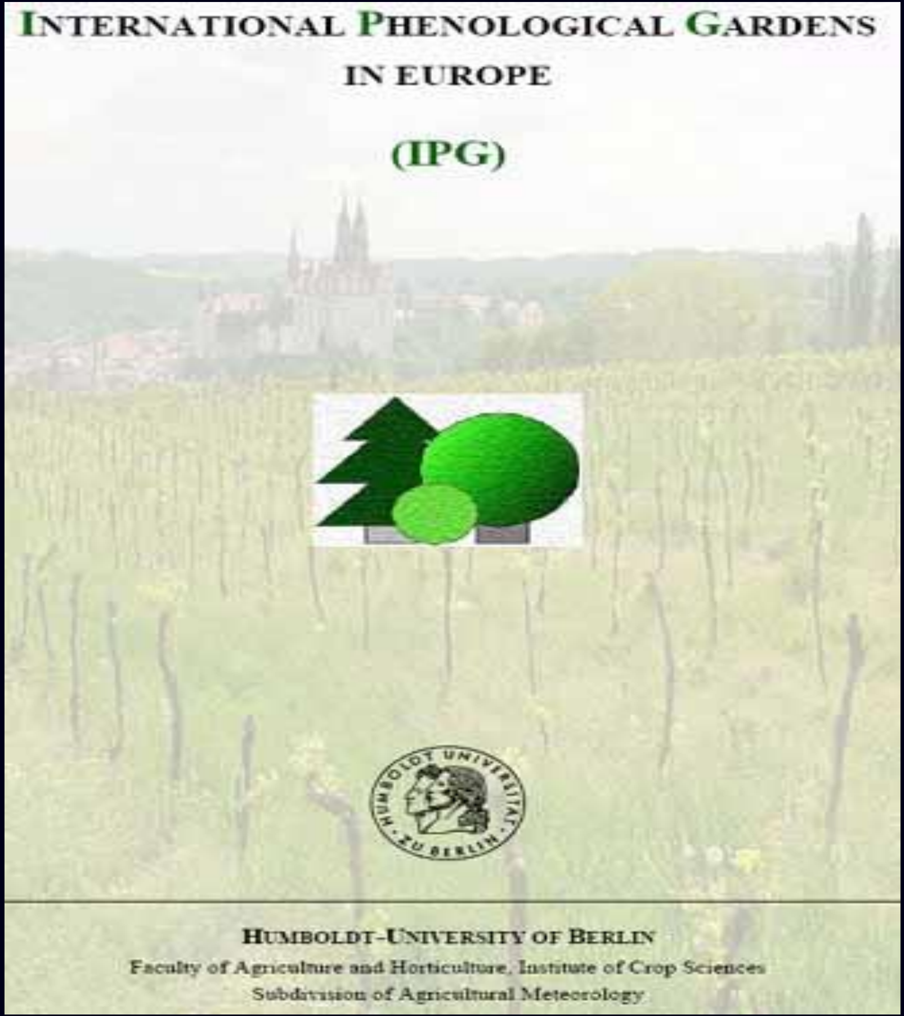
Garcinia indica (Thouars) Choisy

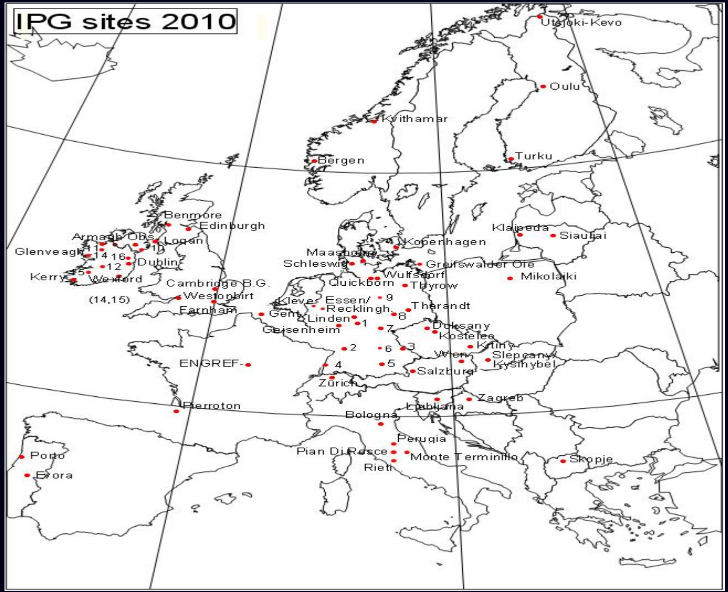
The species prefers evergreen forests, and thrive in relatively low precipitation areas. Therefore, the 'suitable climate space' for the species is limited to the seasonal and spatial variation of temperature, annual rainfall, and precipitation in the wettest period, etc .

A significant variation in monsoon precipitation and temperature variability in the northern Western Ghats. The potential distribution and suitability of *Garcinia indica* in the northern Western Ghats has reached alarming condition and is a big concern .

It may decline the suitable climate space for Garcinia indica, with increasing local to regional level extinction risk in the Western Ghat region of India.

Pramanik, M et al., (2017). Climate Risk Management
doi: https://doi.org/10.1016/j.crm.2017.11.002

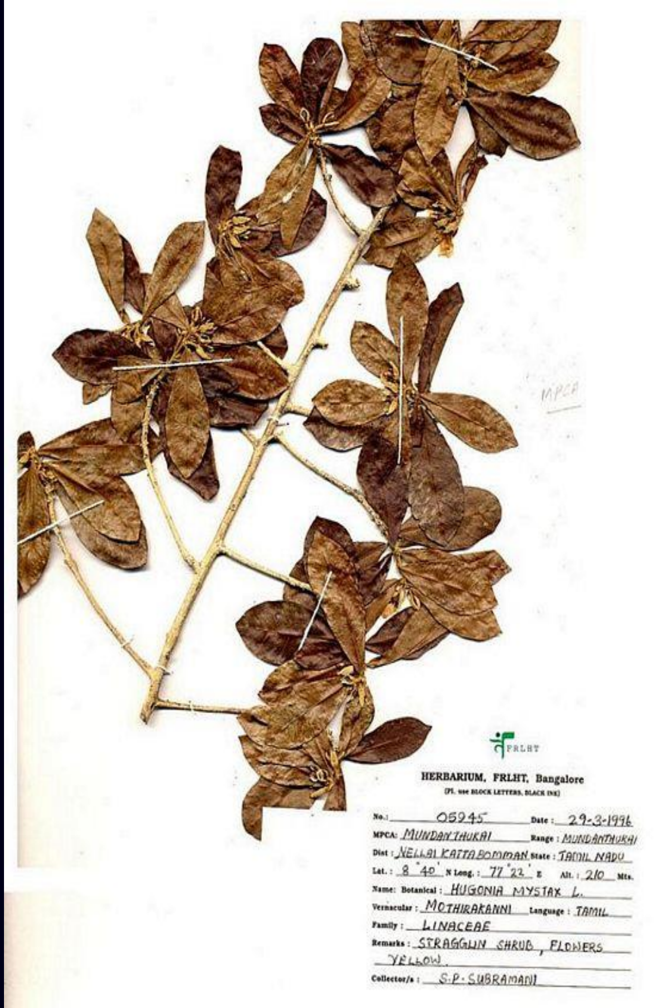




A new Phenological Garden at Armagh Observatory, Ireland

Phenology based on Herbarium Specimens

- As herbaria are increasingly being digitized worldwide, more data are becoming available for future studies.
- As temperatures continue to rise globally, herbarium specimens are expected to become an increasingly important resource for analyzing plant responses to climate change.
- As efforts to produce digital copies of specimens and label information have amassed large datasets, new approaches for analyzing responses to climate change are rapidly becoming available.
- Studies using herbarium specimen data will continue to help us understand the impact of recent climate change on plant reproductive phenology.



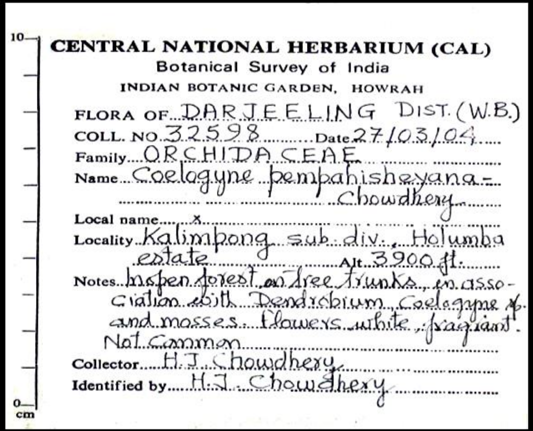
Herbarium Specimens, Field Notes and Flora

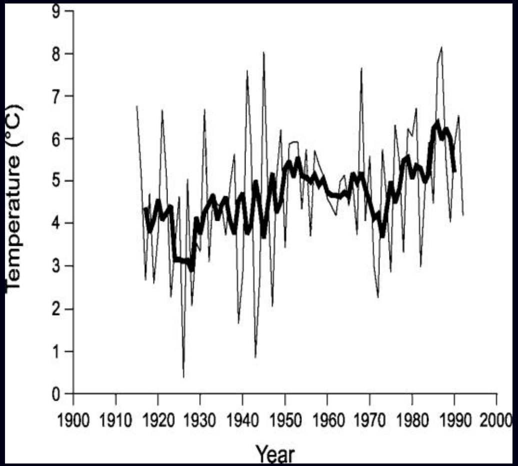
- The observations recorded in the FLELD BOOK while collecting the specimens in the field are transferred to the lable pasted on the right hand corner of the sheet.

- These notes are very important in the identification of the specimen.

- For identification, the scientific method is to first study the characters of the plant, check them with the flora of the region (locality of collection), work through the family, genus and species keys and compare with full description and illustration.

- The use of GPS data appears to be the way forward for the advancement of methods in the study of phenology.


CENTRAL NATIONAL HERBARIUM (CAL)
Botanical Survey of India
INDIAN BOTANIC GARDEN, HOWRAH
FLORA OF DARJEELING DIST. (W.B.)
COLL. NO. 32598 Date 27/03/04
Family ORCHIDACEAE
Name Coelogyne pempahisheyana - Chowdhery
Local name x
Locality Kalimpong sub. div., Holumba estate Alt. 3900 ft.
Notes. In open forest on tree trunks, in association with Dendrobium, Coelogyne & and mosses. Flowers white, fragrant. Not common
Collector H.J. Chowdhery
Identified by H.J. Chowdhery



American Journal of Botany

American Journal of Botany 99(4): 751–756. 2012.

HERBARIUM SPECIMENS, PHOTOGRAPHS, AND FIELD OBSERVATIONS SHOW PHILADELPHIA AREA PLANTS ARE RESPONDING TO CLIMATE CHANGE[1]

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- *Premise of the study:* The global climate is changing rapidly and is expected to continue changing in coming decades. Studying changes in plant flowering times during a historical period of warming temperatures gives us a way to examine the impacts of climate change and allows us to predict further changes in coming decades. The Greater Philadelphia region has a long and rich history of botanical study and documentation, with abundant herbarium specimens, field observations, and botanical photographs from the mid-1800s onward. These extensive records also provide an opportunity to validate methodologies employed by other climate change researchers at a different biogeographical area and with a different group of species.
- *Methods:* Data for 2539 flowering records from 1840 to 2010 were assessed to examine changes in flowering response over time and in relation to monthly minimum temperatures of 28 Piedmont species native to the Greater Philadelphia region.
- *Key results:* Regression analysis of the date of flowering with year or with temperature showed that, on average, the Greater Philadelphia species studied are flowering 16 d earlier over the 170-yr period and 2.7 d earlier per 1°C rise in monthly minimum temperature.
- *Conclusions:* Of the species studied, woody plants with short flowering duration are the best indicators of a warming climate. For monthly minimum temperatures, temperatures 1 or 2 mo prior to flowering are most significantly correlated with flowering time. Studies combining herbarium specimens, photographs, and field observations are an effective method for detecting the effects of climate change on flowering times.

Int. J. Plant Sci. 166(4):663–670. 2005.

1058-5893/2005/16604-0012$15.00

HERBARIUM DATA REVEAL AN ASSOCIATION BETWEEN FLESHY FRUIT TYPE AND EARLIER FLOWERING TIME

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Herbarium phenology data were evaluated and then applied in a phylogenetically independent contrast study in which flowering times were compared between fleshy and nonfleshy-fruited plants growing in the north-temperate provinces of Uppland and Södermanland, southeastern Sweden (59°–60°N). To evaluate herbarium phenology data, flowering-time information taken from herbarium specimens in the Swedish Natural History Museum (S) was compared with two independent field phenology data sets. Herbarium collections and the field studies were restricted to the province of Uppland. Flowering times derived from herbarium specimens correlated equally well with each of the two field-phenology data sets as the field phenology data sets did to each other. Differences between flowering times derived from field and herbarium collections were not affected by the number of herbarium specimens used. However, these differences in flowering times were affected by flowering season such that herbarium-derived flowering times were later for early spring-flowering species and earlier for late summer-flowering species when compared with flowering times derived from field data. In the phylogenetically independent contrast study of mean flowering times in fleshy- compared with nonfleshy-fruited plants, herbarium data were compiled for 77 species in 17 phylogenetically independent contrasts. Flowering time was found to be earlier for fleshy-fruited taxa, illustrating the evolutionary interdependence between flowering and fruiting phases and the constraining effects of a north-temperate climate on phenology evolution. This study shows that herbaria are reliable and time-saving data sources for comparative phenology studies and allow for studies at large phylogenetic and geographic scales that would otherwise be impossible.

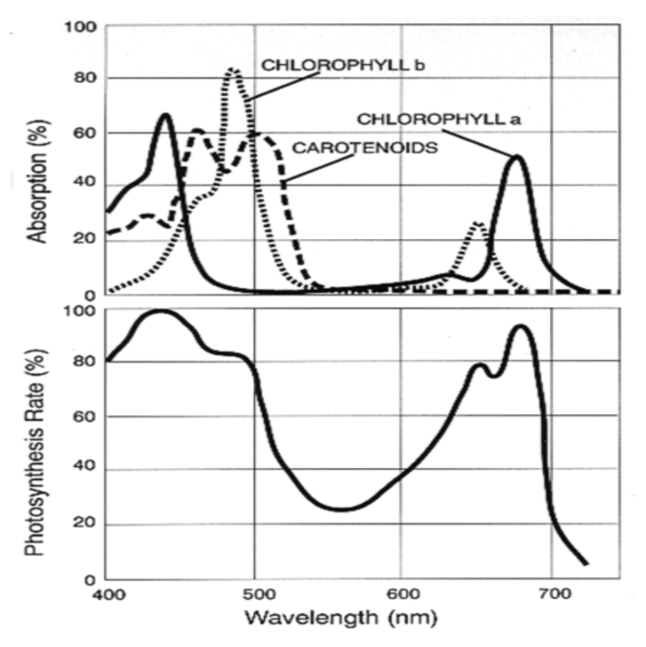
Impacts of Climate Change

Remote Sensing

- Synoptic coverage and repeated temporal sampling from remote sensed data have great potential for monitoring vegetation dynamics.

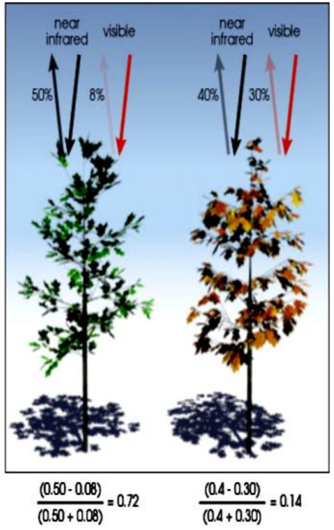
- One of the most striking events in spring is the first appearance of foliage, generally called as green wave.

- This prominent event will be captured through satellite images, which can be used to calibrate remote sensing data.

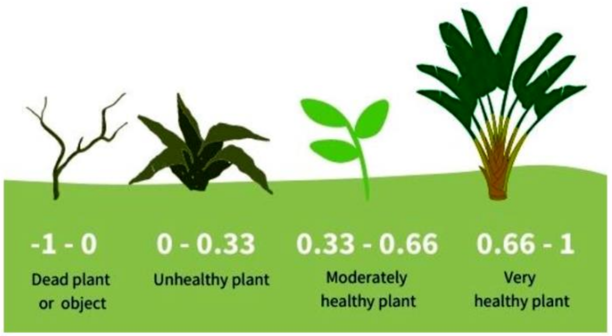


Normalized Difference Vegetation Index (NDVI)

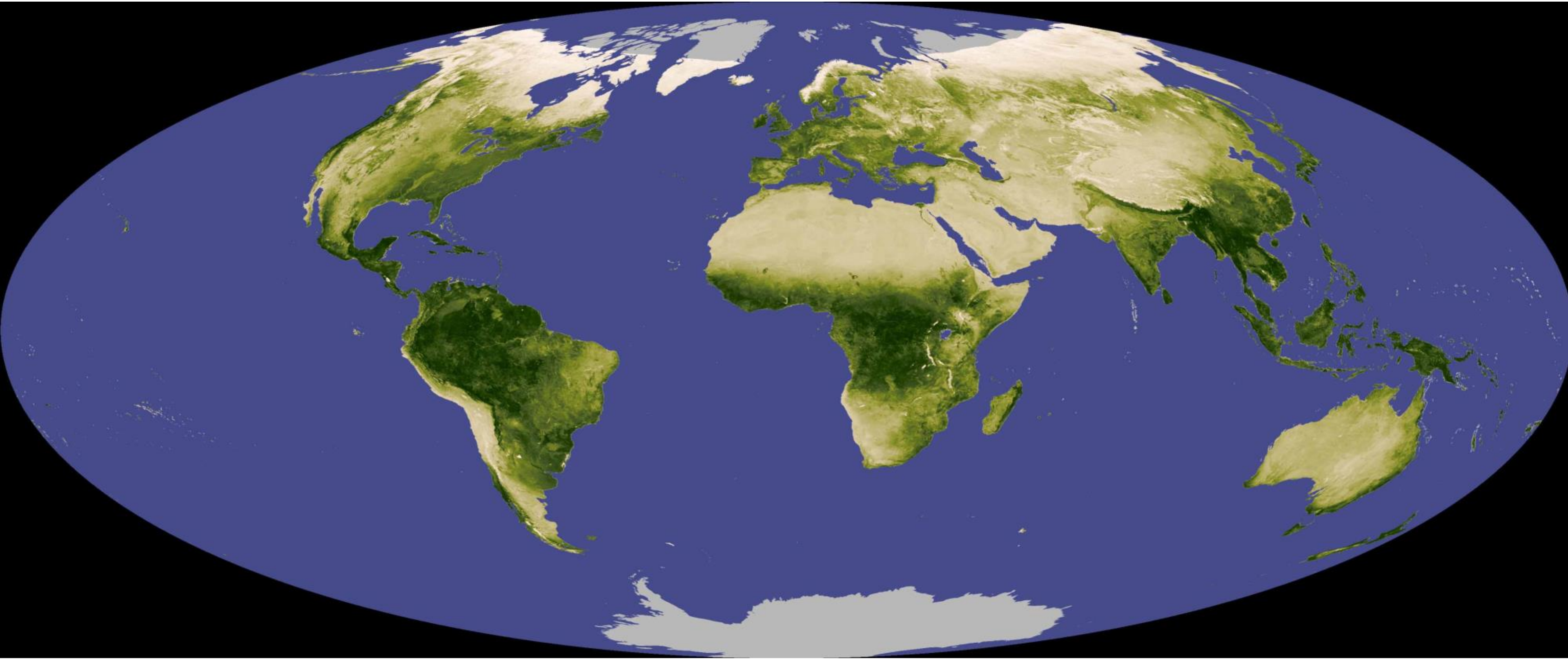
- NDVI is a valuable way to understand vegetation health and land use remotely.
- NDVI is the most commonly used index, due to its versatility and reliability in reporting general biomass.
- The NDVI is a dimensionless index that describes the difference between visible and near-infrared reflectance of vegetation cover and can be used to estimate the density of green on an area of land (Weier and Herring, 2000).
- High NDVI values (approximately 0.6 to 0.9) correspond to dense vegetation such as that found in temperate and tropical forests or crops at their peak growth stage.



Above: NDVI is an indicator of vegetation health based on how plants reflect different light waves. (Credit: NASA)



Green Wave Effect



NDVI Index at global extent, data has spatial resolution of 1-8 km and 10-15 day temporal frequency and height of 250 to 500 M for entire globe

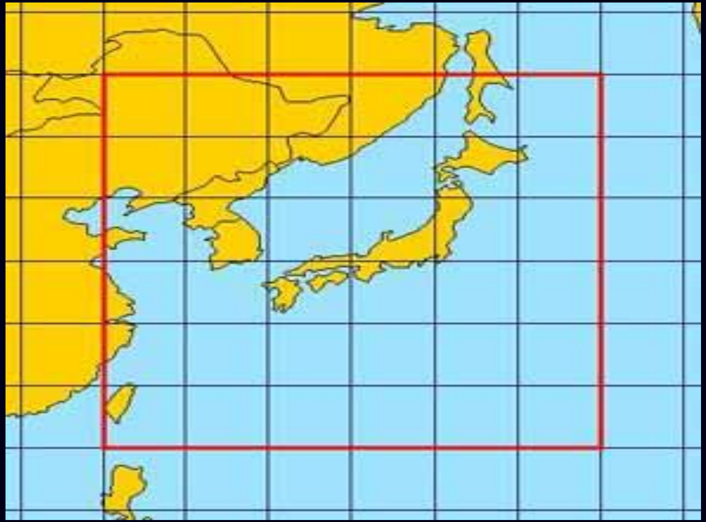
Impacts of Climate Change

Remote Sensing – NDVI Index

- Zhoe et al (2001) analyzed the NDVI data 1981 to 1999 showed that 61 % persistent increase in growing season in Central Europe which mainly consist of forests and woodlands.

- Growing season increased 18 days in Eurasia and 12 days in North America caused by early spring and late autumn.

- NDVI has created continuous European vegetation phenology for 1982 to 2001. It found strong seasonal and inter –annual variability in European territories.

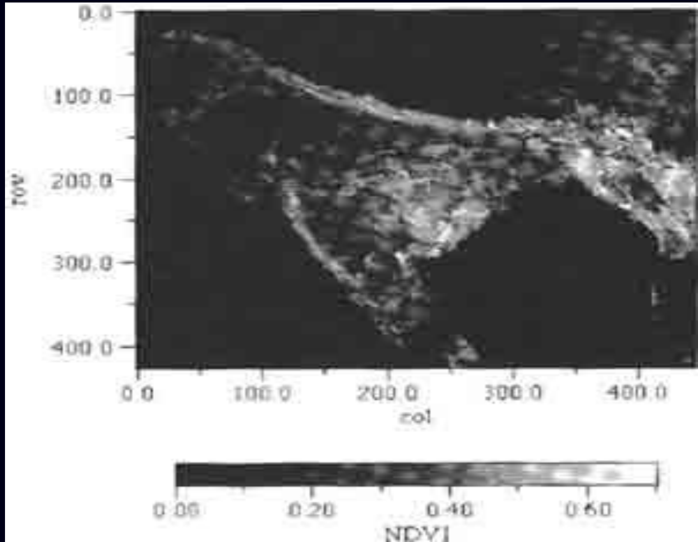


L Marcelo D.Nosette *et al* 2008. Long-term Satellite NDVI Data Sets: Evaluating Their Ability to Detect Ecosystem Functional Changes in South America. *Sensors, 8*(9): 5397-5425

Impacts of Climate Change

Remote Sensing – NDVI Index

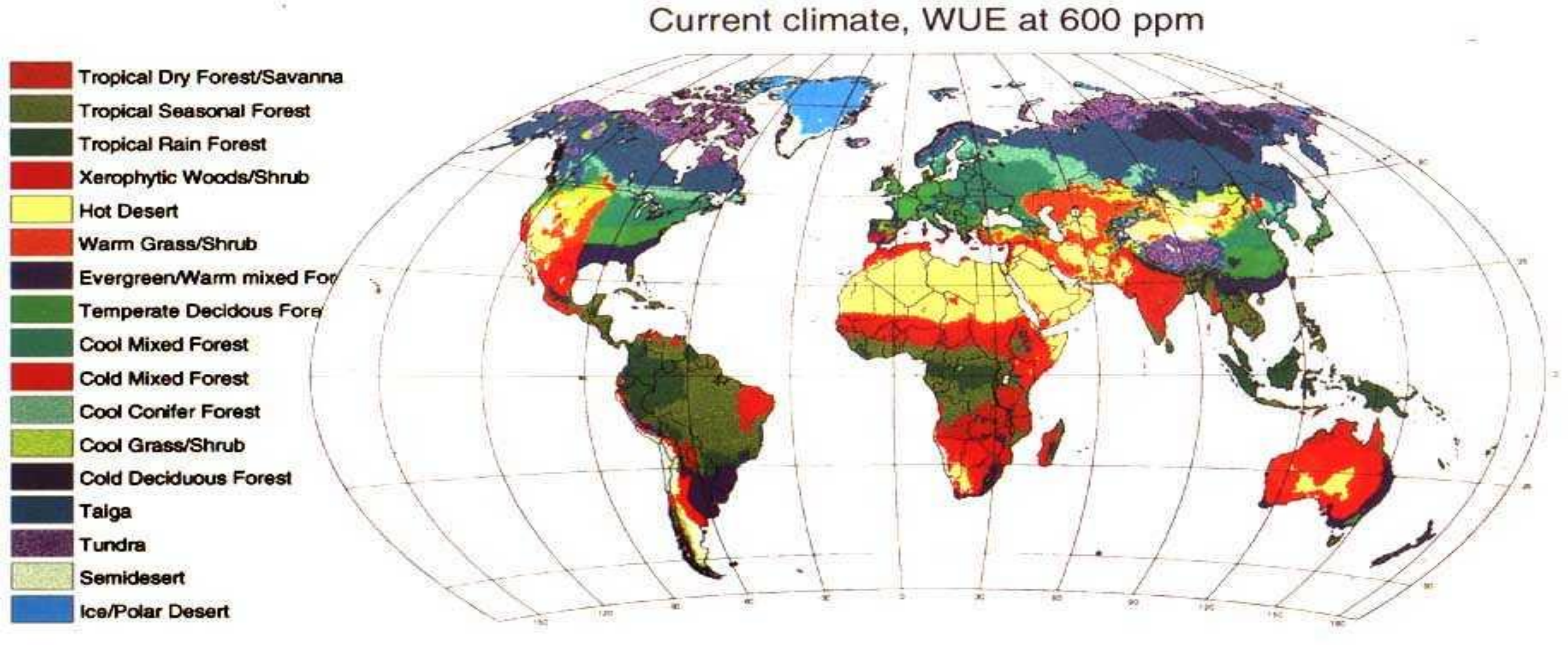
- In Denmark, Hogda et al (2001) found that a delay of spring in the alpine belts and borel zones.
- Chen et al (2005) found that growing season in China had been extended by 1.4 to 3.6 days/Year in Northern parts.
- NDVI data compared with tree rings in North America and found that correlates only in June and July.
- This may imply that advances in Spring and delay in autumn of growing season are less important to the physiological status of trees.



Global Biome Maps

- Global Biome Maps (GBM) have been widely used to assess the impacts of simulated past and future climate change on ecosystems.
- The amount of change between two biome maps is usually measured by the fraction of cells that change the class.
- This is a combination of small number of plant functional types and climatic variables to simulate and develop vegetation classes .
- This vegetation models assess the magnitude of climatically induced changes from simulate global biome maps and its visual comparisons.

Global Biome Maps



Climate change and pollinators

Bee pollination in *Aegle marmelos*

Many plants distribute their pollen via mobile arthropods

Image source: Market wallpapers

"Pollination is not just a free service, but one that requires investment and stewardship"

– United Nations Environment Programme

Plant- Pollinator Interactions

- To adapt to climate change, some flowers are darkening to protect themselves from the sun's radiation.

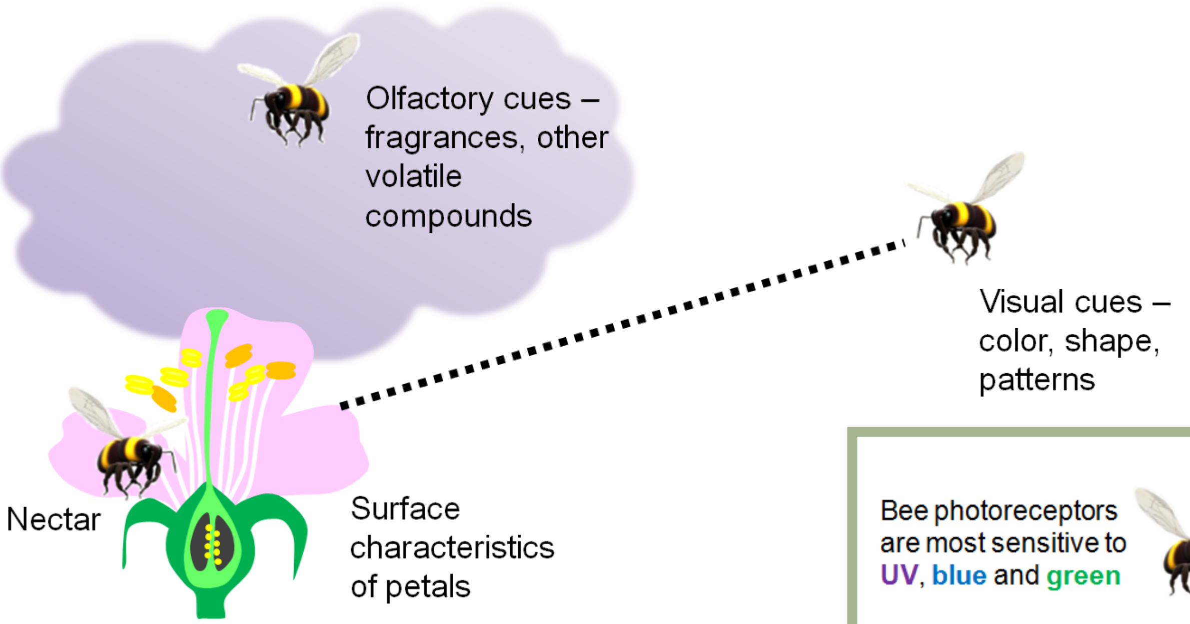
- Around the globe, plant and animal species have tweaked their reproductive strategies, shifted their home ranges, and altered their appearance as they quickly adapt to the effects of climate change—and flowers are no exception.

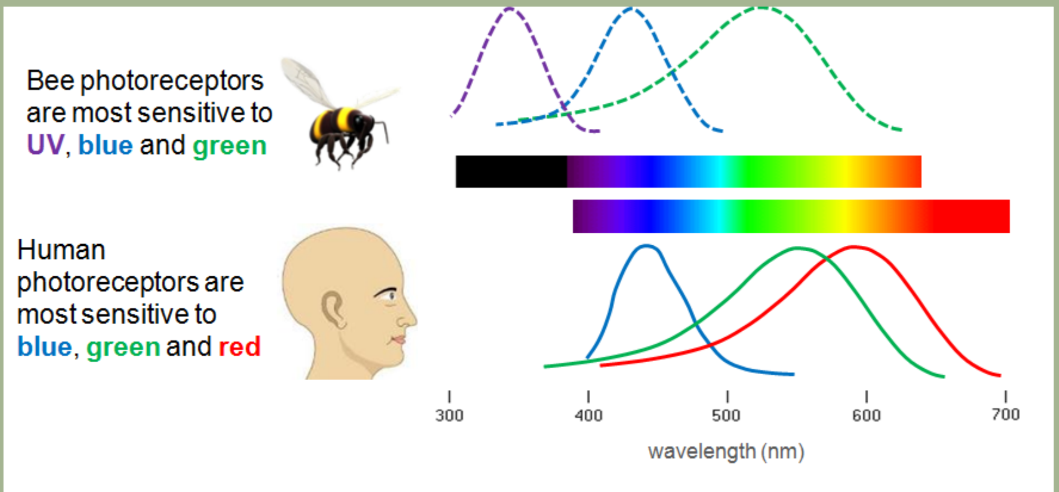
- Pollinators are more attracted to petals with a "bull's-eye" pattern—brighter petal tips, or less pigment, with darker, more pigmented centers. But when the whole flower gets darker, "pollinators might miss the flowers entirely.

- As climate change continues to intensify, these changes in floral coloration can disrupt plant-pollinator interactions.

Pollinators perceive the higher levels of UV-absorbing pigments as a darker hue, which could be confusing when they try to scope out colorful flowers to land on. Image by PublicDomainPictures from Pixabay under free for commercial use license

What attracts pollinators?



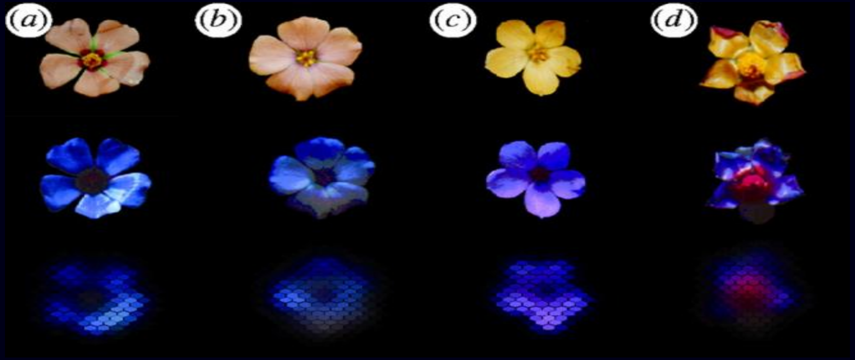


Bee spectral sensitivity adapted from Arnold, S., Savolainen, V. and Chittka, L. (2009). Flower colours along an alpine altitude gradient, seen through the eyes of fly and bee pollinators. Arthropod-Plant Interactions. 3: 27-43.

Flower pigments also reflect or absorb UV-light which is visible to bees

Visible light

Simulated bee color vision



Bees also have lower spatial resolution than humans, which is represented in the third row

Images (c) Dr Klaus Schmitt, Weinheim, www.uvir.eu; Benitez-Vieyra, S., de Ibarra, N.H., Wertlen, A.M. and Cocucci, A.A. (2007). How to look like a mallow: evidence of floral mimicry between Turneraceae and Malvaceae. Proc. Roy. Soc. B. 274: 2239-2248.

Flowers Are Changing Colors due to Climate Change

- Recent Researches suggests that over the past 75 years, flowers have also adapted to rising temperatures and declining ozone by altering ultraviolet (UV) pigments in their petals.
- Due to prolonged UV exposure, UV-absorbing pigmentation on petals, which protects pollen from UV-damage.
- due to the declining ozone and increasing global warming, flowers are changing their colours.
- UV-pigmentation in flowers increased at a rate of 2% per year from 1941 to 2017.

Argentina anserina
(Rosaceae)

Koski et al., 2020, Floral Pigmentation Has Responded Rapidly to Global Change in Ozone and Temperature. **Current Biology 30, 4425–4431**

Pigment changes could make plants less attractive to pollinators

- Darker petal areas possess UV-absorbing compounds whereas lighter areas are UV reflective and lack UV-absorbing compounds
- The results varied depending on the flower's structure and the region. For flowers with anthers enclosed within petals, pigmentation declined with increases in temperature.
- Climate change may affect pollination through its impact on floral color, with repercussions for plants' reproductive fitness.
- UV radiation can be harmful for a flower's pollen. Pigmentation in plants also affects floral thermoregulation.

Flower colors are changing in response to climate change.
https://www.science.org/content/article/flowers-are-changing-their-colors-adapt-climate-change doi: 10.1126/science.abf0151

- Scientists studied the *Argentina anserina* across four lines of latitude.
- They focused on the centres of the flowers, which look dark to bees.
- Study found that dark centre was larger the nearer to equator flowers grew.
- They predict that as Earth receives more UV light due to global warming, flowers farther from the equator will also evolve these traits.

It may look similar to the naked eye but flower bloom (left) shows a larger area of dark pigmentation under UV light (right). The flowers come from the extreme north (top) and south (bottom) of New Zealand.

Flowers and pollinators evolved physiological compatibilities

Photos by Jack Dykinga; Rob Flynn, USDA-ARS; Hans Hillewaert

Incomplete Pollination

- Happens when the plant is grown in “wrong habitat” for the pollinator

Palatty Allesh Sinu, Central University of Kerala. sinupa@gmail.com

Disa uniflora **vs.** ***Meneris tulbaghia*** **(a saturnid butterfly) - compared rocky gorges (native habitat) with valleys (Johnson & Bond 1992)**

Incomplete Pollination

Amomum subulatum vs. *Bombus haemorrhoidalis* (Sinu & Shivanna 2008)

? Should plants schedule flowering season along with the breeding season of bees

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Incomplete Pollination

How plants enhance pollination success?

- **Deciding flowering phenology time**
- **Regulating anthesis time**
- **Regulating the flower opening and closing pattern across day/s**
- **Regulating the amount of pollen that is released to pollinators per visit**

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A deceit Plant : *Ophrys speculum*

- Some plants take advantage of the sex drive of certain insects…Certain orchids look like female wasps, and even smell like them!
- *Ophrys* in Europe, 9 genera in Australia.
- Sexual deception where the flower attracts male pollinators by mimicking a female of the same species (e.g. scent, colour, “hair”).
- Typically, pollination by sexual deception is highly specific and usually only involves one insect species.
- In the process, wasps pollinate the orchid, but the male wasp only gets frustrated!
- 1/3 of the ~25k species of orchids are pollinated by deceit, giving no reward (only 400 are sexually deceptive).

Why there are pollen and nectar robbers?

Tubular flowers originally meant for bird or moth pollination, but why small short-tongued halictid females (sweat bees) are interested in them?...... thief!

20% - 30% of plants and animals species likely at "increased risk of extinction"

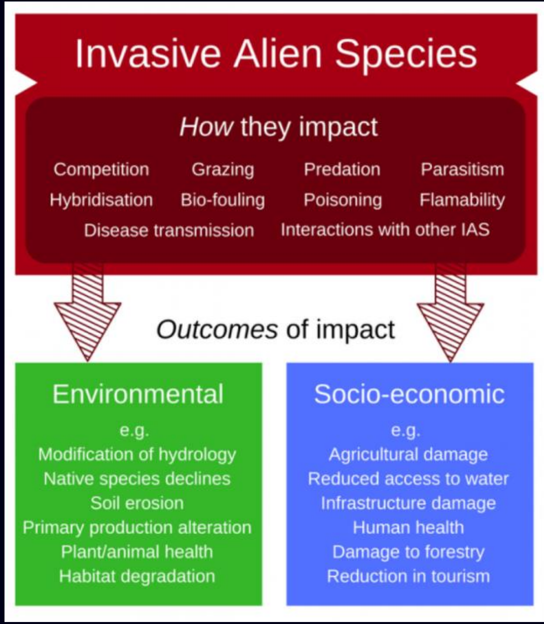
if ΔT 1.5°C - 2.5°C (above 1990 temperature)

Bee pollination in *Aegle marmelos*

- Changes in phenological events across trophic levels would cause the temporal disruption of species interactions, such as phenological mismatches between plants and their pollinators.

Invasive Alien Species and Climate Change

- Invasive alien species (IAS) are introduced into places outside of their natural range, negatively impacting native biodiversity, ecosystem services or human wellbeing.
- IAS are one of the biggest causes of biodiversity loss and species extinctions, and are also a global threat to food security and livelihoods.
- IAS are compounded by climate change. Climate change facilitates the spread and establishment of many alien species and creates new opportunities for them to become invasive.
- IAS can reduce the resilience of natural habitats, agricultural systems and urban areas to climate change. Conversely, climate change reduces the resilience of habitats to biological invasions.



https://www.iucn.org/resources/issues-briefs/invasive-alien-species-and-sustainable-development

Prosopis juliflora

- It shows high level of water consumption which can lower the ground water table.
- It also takes over pastoral grasslands and uses scarce water.
- Livestock which consume excessive amounts of seed pods are poisoned due to neurotoxic alkaloids. Native to South America.

Lantana camara

- It was popularly grown for attracting butterflies and for beautification of gardens but has now spread throughout the forests and forms a dominant part of the undergrowth.
- Its roots exhibit allelopathy which inhibits the growth of other plants around it. The origin of this plant can be traced to American tropics.

Acacia auriculiformis

- Another Australian native, this tree is widely grown for its fast growth rate and use of wood pulp in paper industry.
- It exhibits low water and fertilizer requirements which make it an extremely invasive species if not managed properly.

Leucaena leucocephala

- Commonly used for reforestation purposes, this tree produces leaves and seeds which contain an amino acid called Mimosine which can be toxic to other plants around it.
- This makes the plant highly invasive. It is native to American tropics.

Eichhornia crassipes

- (Water hyacinth) of family Pontederiaceae is a native of South America, is one of the worst aquatic weeds in the world.
- It is introduced into India in 1896 as an ornamental plant at botanical garden at Bengal (Biswas & Calder, 1954).
- This plant has become an environmental and social menace in most of the water bodies of the country.

Top Invasive species of India

- Invasive plant species have posed serious threat to the native flora of India (Sharma et al., 2005; Kohli et al., 2004).

- *Ageratum conyzoides,*
- *Artemisia scoparia,*
- *Bidens pilosa*
- *Cassia occidentalis*
- *Chenopodium ambrosioides,*
- *Datura stramonium,*
- *Eichhornia crassipes*

- *Eupatorium adenophorum,*
- *Eupatorium odorataum,*
- *Lantana camara,*
- *Mikania micrantha,*
- *Parthenium hysterophorus*
- *Pistia stratiotes*
- *Prosopis juliflora*
- *Tagetes minuta*

Invasive Species and Climate Change

- Invasive species tend to have high dispersal rates, rapid growth rates with short generation times, and high capacity to tolerate broad environmental conditions.
- Collectively, these traits greatly enhance their ability to cope with rapid changes in abiotic and biotic conditions such as those associated with climate change.
- Plants selected for introduction for ornamental or agricultural purposes have broad climatic tolerances that favor their rapid establishment and growth, thus enhancing their potential for invasiveness in response to climate and land-use changes.

Morphological parameters of Plants in different time intervals

(1889-2011)

Satellite image of Karaikal District (Coastal) before and after tsunami

Heliotropium zeylanicum (Burm.) Lam.

Heliotropium zeylanicum (Burm.) Lam.

Plant parts	Flora of British India (Hooker, J. D. 1889)	Flora of the presidency of Madras (Gamble, J. S. & CEC Fiacher. 1935)	The Flora of the Tamilnadu Carnatic (Matthew, K. M. 1983)	Flora of the Karaikal District (Sambandan 2021 unpubl)
Habit		Herb	Erect herb, up to 60 cm high	Perennial herb, up to 30 cm high
Leaves		2.5 x 0. 25 cm	1 – 2 x 0.3 – 0.4 cm	1 - 1.8 x 0.1 - 0.2 cm
Petiole			Up to 0.5 mm long	1mm long
Racemes	5 – 15 cm	Elongate	Up to 8 cm ,long	Up to 20 cm long
Pedicel		-	Up to 0.3 mm long	1 mm long
Calyx-lobe 5	0.25 cm	-	1.5 mm long	1 mm long
Corolla-lobe 5	0.43 cm	-	Tube 1.5 mm long, lobe 2.5 mm long	Tube 1.1 mm long, lobe 01 mm long
Anther		-	01 mm long	5 mm long
Ovary		-	0.7 mm long	6 mm long
Nutlets	0.2 cm	-	01 mm long	0.8 – 02 mm long

Psilotrichum nudum (Heyne ex Wall.) Moq.

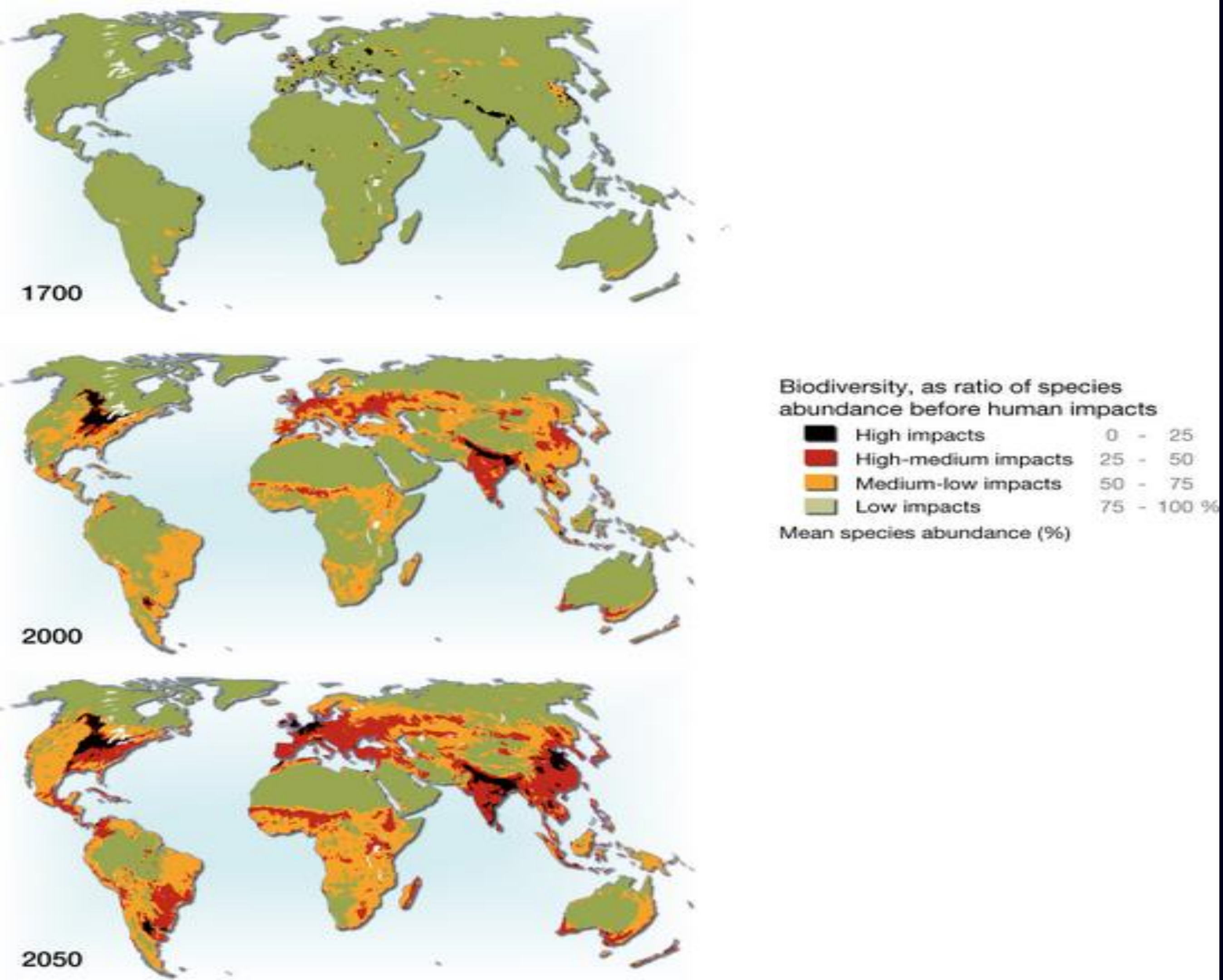
Psilotrichum nudum (Heyne ex Wall.) Moq.

Plant parts	Flora of British India (Hooker, J. D. 1889)	Flora of the presidency of Madras (Gamble, J. S. & CEC Fiacher. 1935)	The Flora of the Tamilnadu Carnatic (Matthew, K. M. 1983)	Flora of the Karaikal District (Sambandan 2011 unpubl)
	2 – 3 -fid	Undershrub many-branched	Herb	Erect or spreading undreshrub
Leaves	1 ½ - 3 in	7.5 x 2.5 cm	Up to 1.5 – 2.5 x 0.8 – 1.5 cm	1.8 - 3 x 1 - 1.4 cm,
Petiole	-	-	0.4 mm long	05 mm long
Racemes	1/3 1 ½ in	.5 – 1in long	-	Up to 1.5 cm long
Bracts	-	-	1.7 mm long	1.5 mm long
Bracteoles	-	-	1.5 x 2 mm long	1.4 – 1.5 mm long
Tepals5	-	-	Inner 3 smaller, 3.5 mm long	Inner 3 smaller, 3.2 mm long
Stamens 5	-	-	Filament 1.5 mm long	Filament 1.3 – 1.5 mm long
Anther	-	-	0.4 mm long	0.2 – 0.3 mm long
Ovary	-	-	0.8 mm long	0.5 - 0.7 mm long
Style	-	-	0.9 mm long	01 mm long
Utricle	-	.25 in long	-	-

Phyllanthus rotundifolius Klein ex Willd.

Phyllanthus rotundifolius Klein ex Willd.

Plant parts	Flora of British India (Hooker, J. D. 1889)	Flora of the presidency of Madras (Gamble, J. S. & CEC Fiacher. 1935)	The Flora of the Tamilnadu Carnatic (Matthew, K. M. 1983)	Flora of the Karaikal District (Sambandan 2021 unpubl)
	6 – 24-fid	Prostrate or slightly ascending fleshy herb	-	Herb, up to 30 cm high
Leaves	¼ - 1/3 in	.25 in long diam	-	05 - 08 x 05 - 07 mm
Petiole	Minute	-	-	01 mm long
Stipule	Minute, subulate	-	-	01 mm long
Tepals 5	-	-	-	1.5 mm long
Anther	-	-	-	0.2 mm long
Ovary	-	-	-	0.5 mm long
Capsule	1/ 16 – 1/12 in	-	-	02 mm long


1700
2000
2050
Biodiversity, as ratio of species abundance before human impacts
High impacts 0 - 25
High-medium impacts 25 - 50
Medium-low impacts 50 - 75
Low impacts 75 - 100 %
Mean species abundance (%)

Plant Roots and Climate Change

Two factors that play a key role in climate change - increased climate warming and elevated ozone levels - appear to have detrimental effects on plant roots, their relationship with symbiotic microorganisms in the soil.

Roots sense these thermal changes directly or indirectly. Indirectly sensing is either triggered by the shoot demand of water and nutrient or by the supply of carbon from the shoot to root (Plieth et al., 1999; Heckathorn et al., 2013).

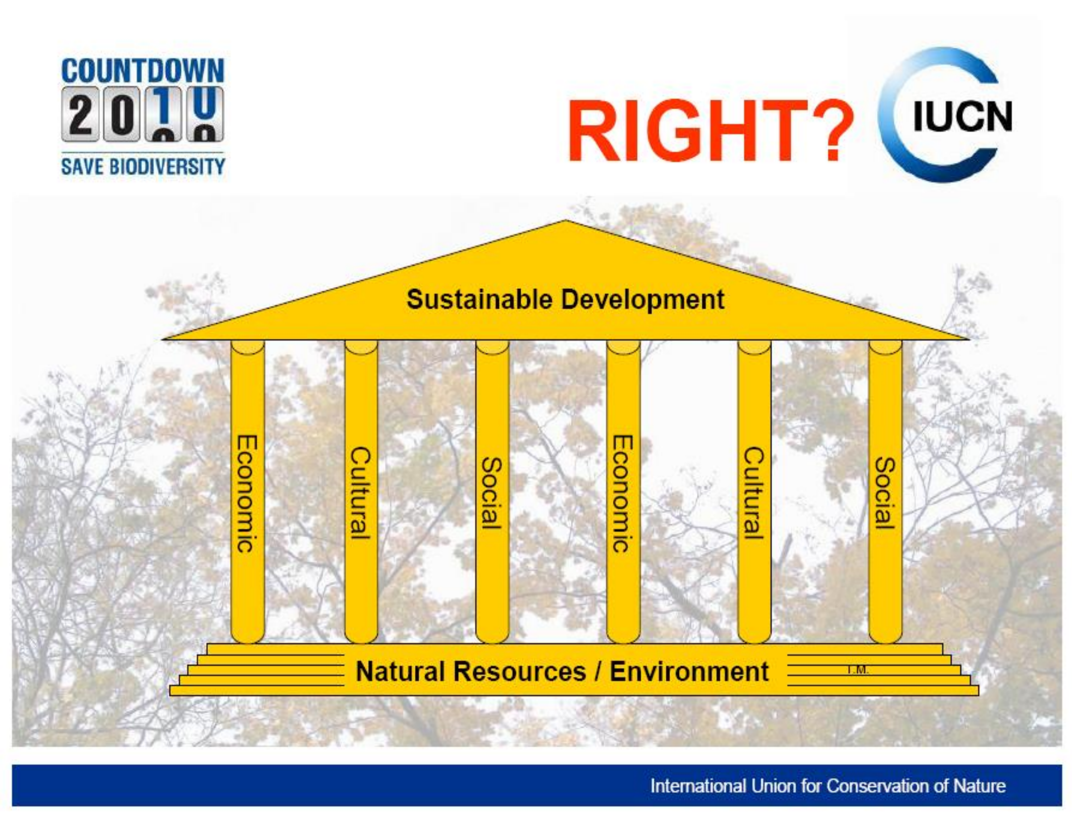
Ozone and warming make the plants weak. Plants try to maximize nutrient uptake, so their roots become thinner and longer as they need to exploit the sufficient volume of soil for resources.

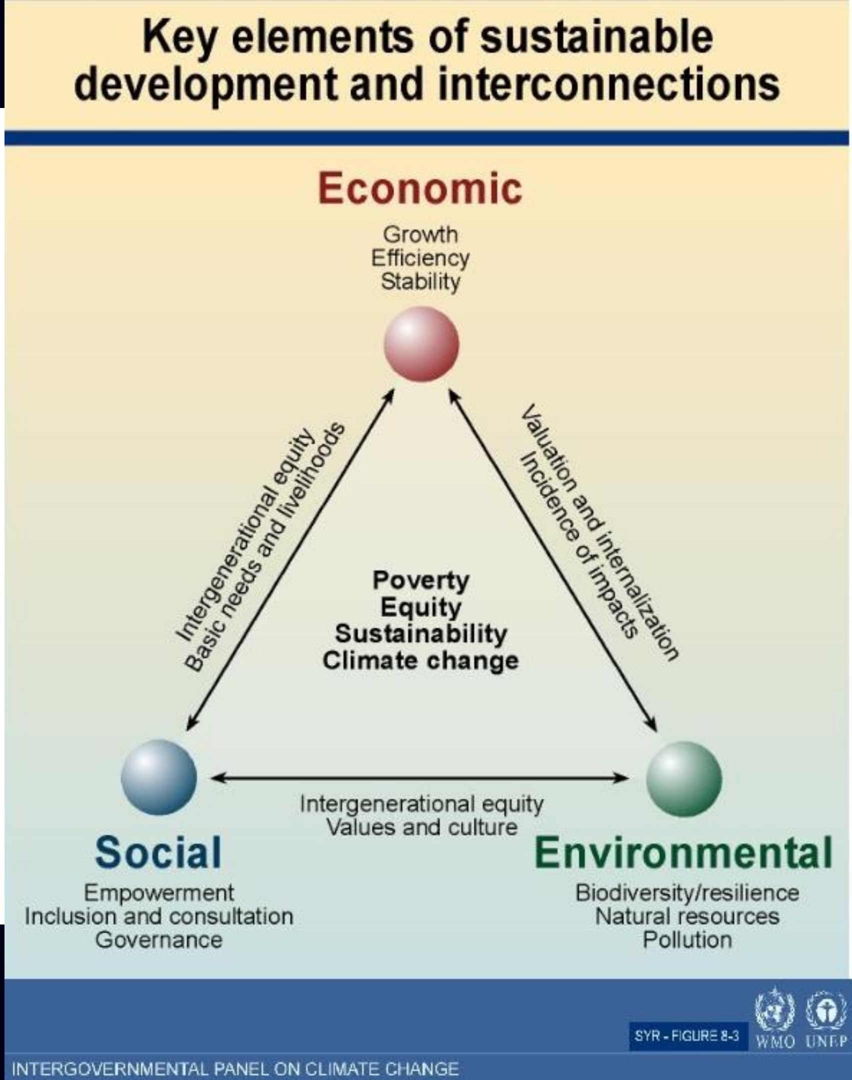
Within–canopy distribution

Amazonian tree –

- The long roots dangling from the crown probably belong to *Philodendrons*
- On the middle and upper branches cluster groups of orchids, bromeliads, and ferns – including staghorn fern
- Low on the trunk are *Arums* & *Philodendrons* with heart-shaped leaves
- This all epiphytes needs some favorable whether conditions.

NATURE MUST HAVE A PRICE!


COUNTDOWN 2010
SAVE BIODIVERSITY
RIGHT?
IUCN
Sustainable Development
Economic
Cultural
Social
Economic
Cultural
Social
Natural Resources / Environment
International Union for Conservation of Nature


Key elements of sustainable development and interconnections
Economic
Growth
Efficiency
Stability
Intergenerational equity
Basic needs and livelihoods
Valuation and internalization
Incidence of impacts
Poverty
Equity
Sustainability
Climate change
Intergenerational equity
Values and culture
Social
Empowerment
Inclusion and consultation
Governance
Environmental
Biodiversity/resilience
Natural resources
Pollution
SYR - FIGURE 8-3
WMO UNEP
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE


Climate Change
A Sign of The
End Times
www.andrewcorbett.net


We are one among you, please conserve us too…
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Thank You…


Have a
nice
day.