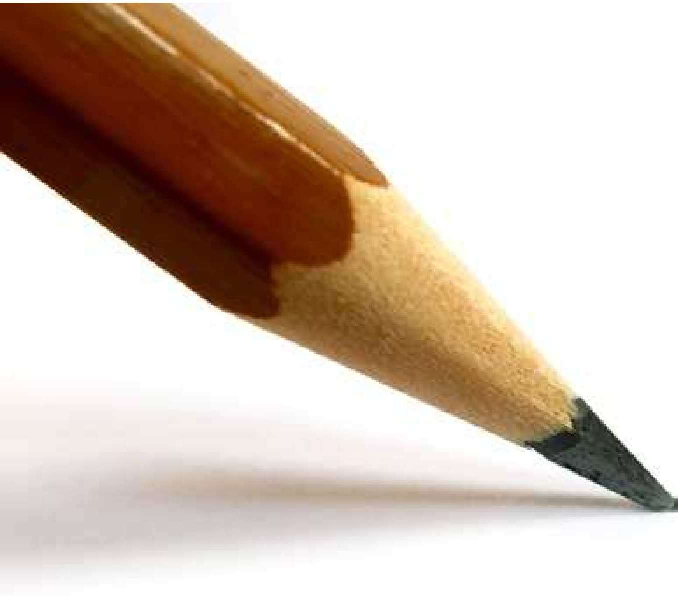


Change of vegetation periods and its impact on forestry and agriculture

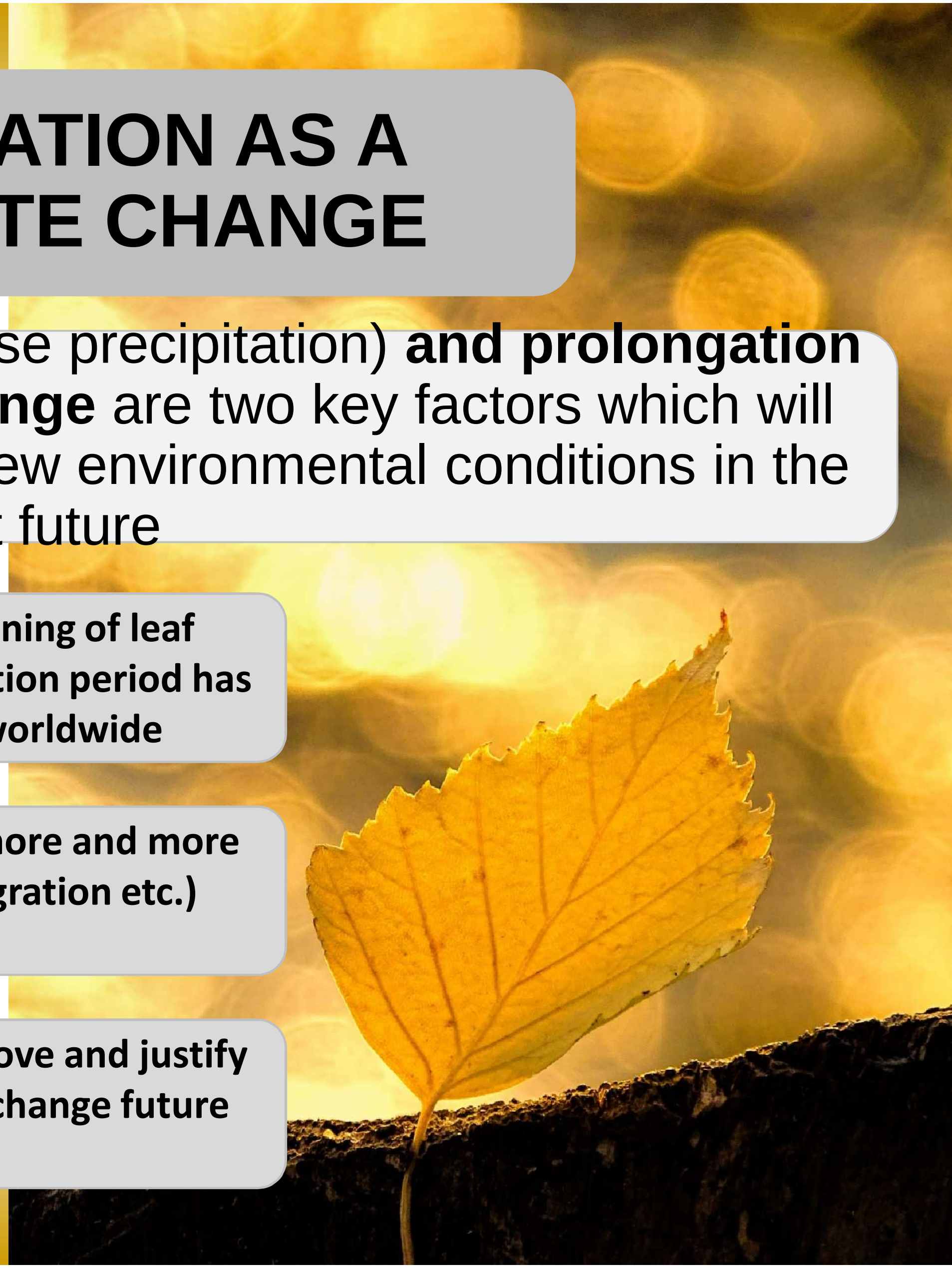
NATURE OBSERVATION AS A SIGNAL OF CLIMATE CHANGE

Extreme climate events (heat waves, intense precipitation) **and prolongation of vegetation periods due to climate change** are two key factors which will demand adapt of farmers and foresters to new environmental conditions in the near and distant future

In the 20^{th}-21^{st} centuries, plant development phases, e.g., beginning of leaf unfolding, first harvest, and beginning, duration and end of vegetation period has changed dramatically as evidenced by studies in Europe and worldwide

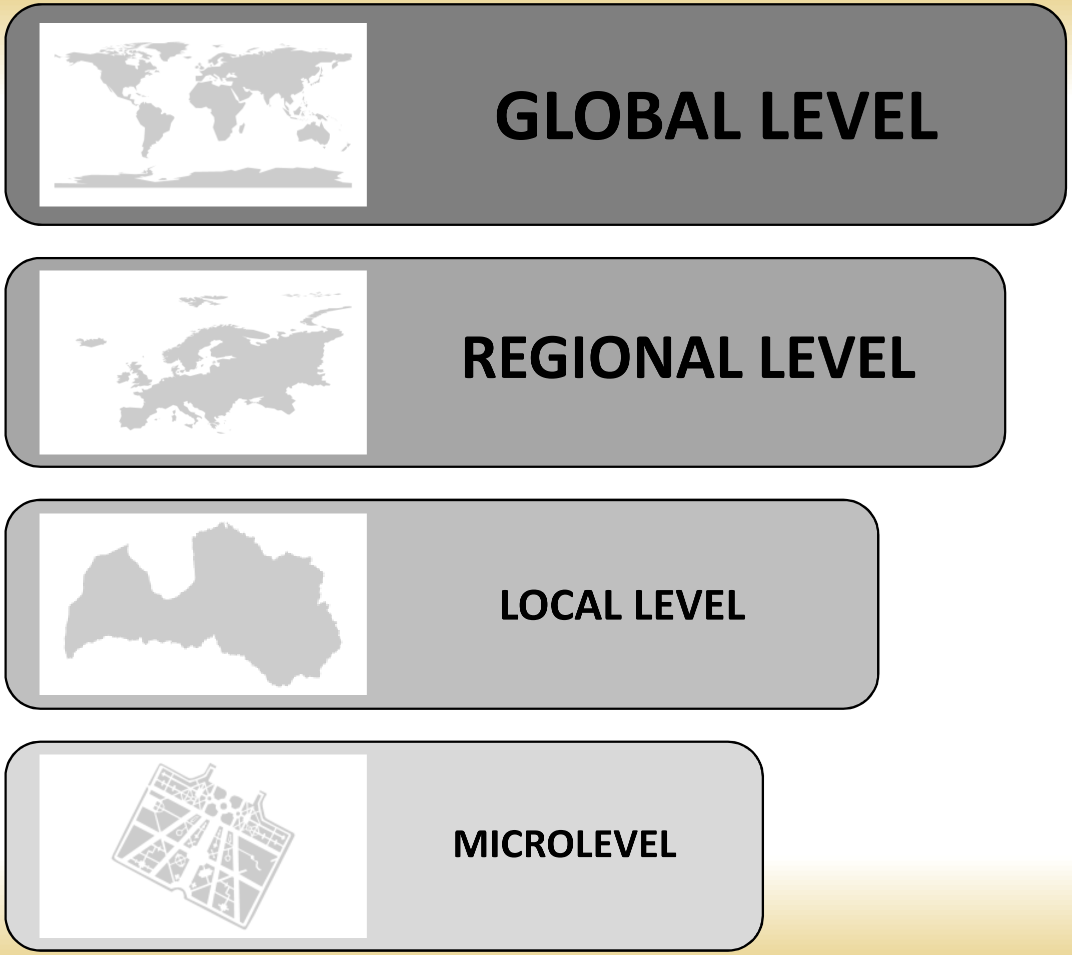
Plants and animals are sensitive to environmental changes, thus more and more bioclimatic data (leaf unfolding, coloring, fruit ripening, bird migration etc.) are used as bioindicators of climate change

Nature observation is probably the easiest and cheapest way to prove and justify climate change and that can help in forecasting future of climate change future and in development of adaptation scenarios



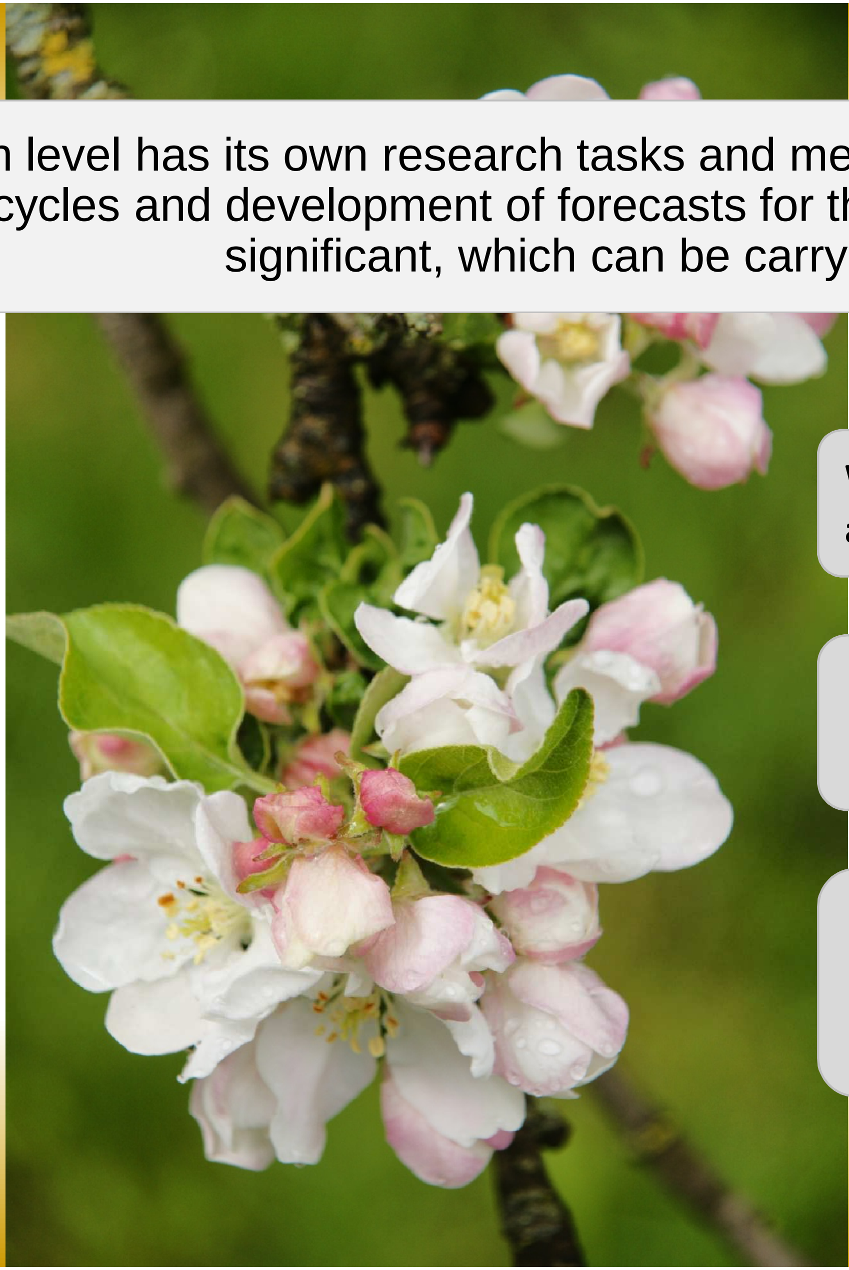
The climate, which is a determinative factor of plant development, is affected as well as by global phenomena, such as atmospheric circulation, ocean currents, as by microclimatic conditions

Therefore, studies of bioclimatology or studies on natural rhythms of environment are carried out at several levels



Levels of nature observation

Each level has its own research tasks and methods, *e.g.*, for analysis of forest productivity, CO_2 cycles and development of forecasts for the future, the importance of global research is significant, which can be carry out by analysis of satellite images

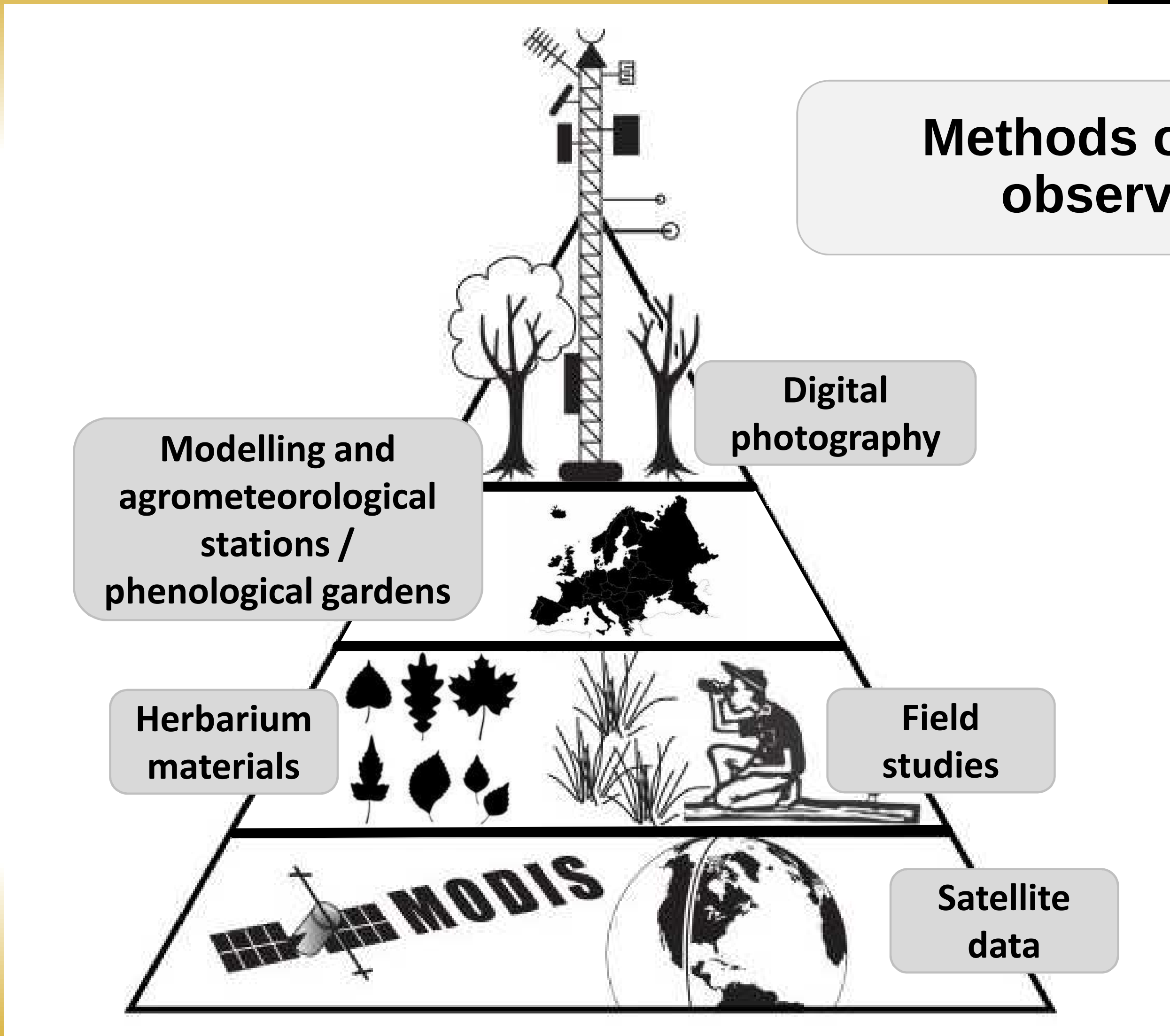


Whereas, for calibration of satellite images field studies are required, usually carried out by voluntary observers

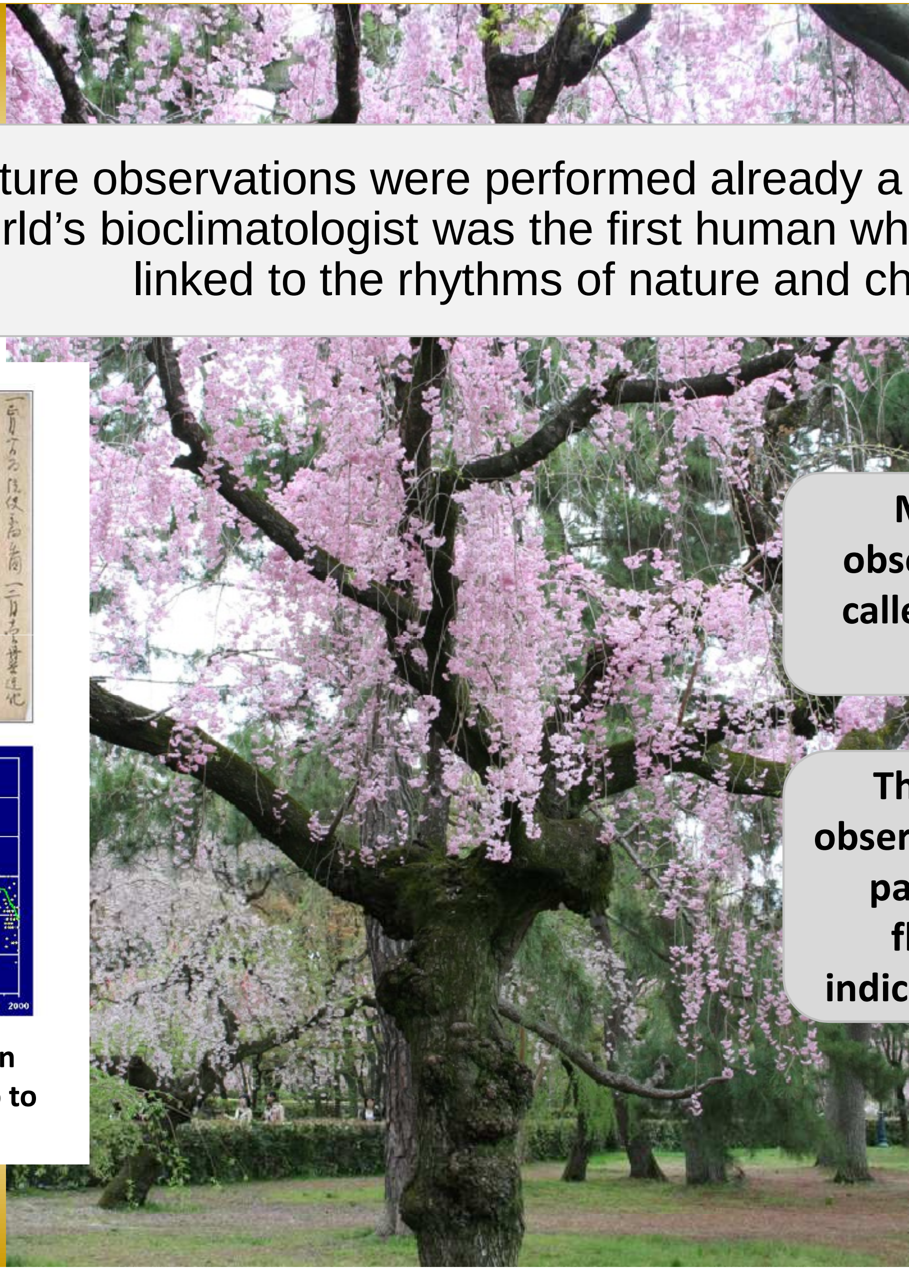
More and more often the studies uses digital videorecorders or automatic digital cameras connected to the internet for taking high quality digital images

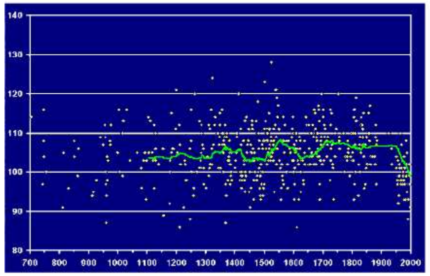
Frequently direct microclimatic conditions play the key role in development of plants, for example, beginning of bird-cherry tree flowering at a riverbank may differ significantly from its flowering in a forest

Methods of nature observation



Nature observations were performed already a long time ago – the first world's bioclimatologist was the first human whose daily life was tightly linked to the rhythms of nature and changes in them





Beginning of cherry flowering in Kyoto, Japan, from year 705 up to present

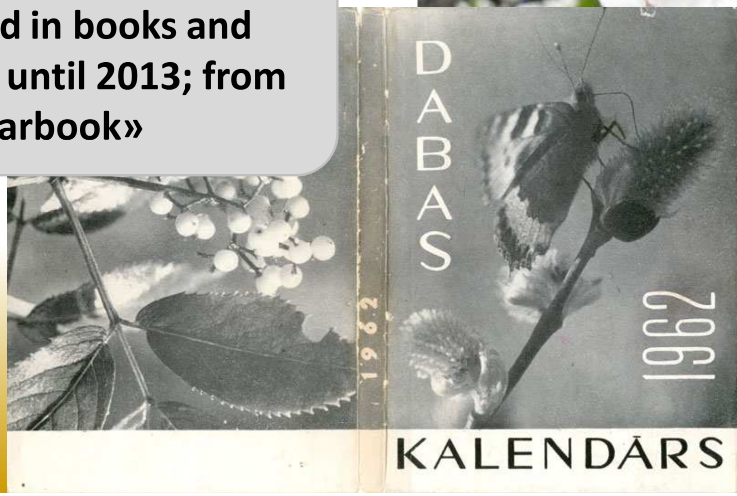
Many national calendars are based on the observation of nature, e.g., the ancient Latvians called April as a month of juice, May – month of leaves or dandelion etc.

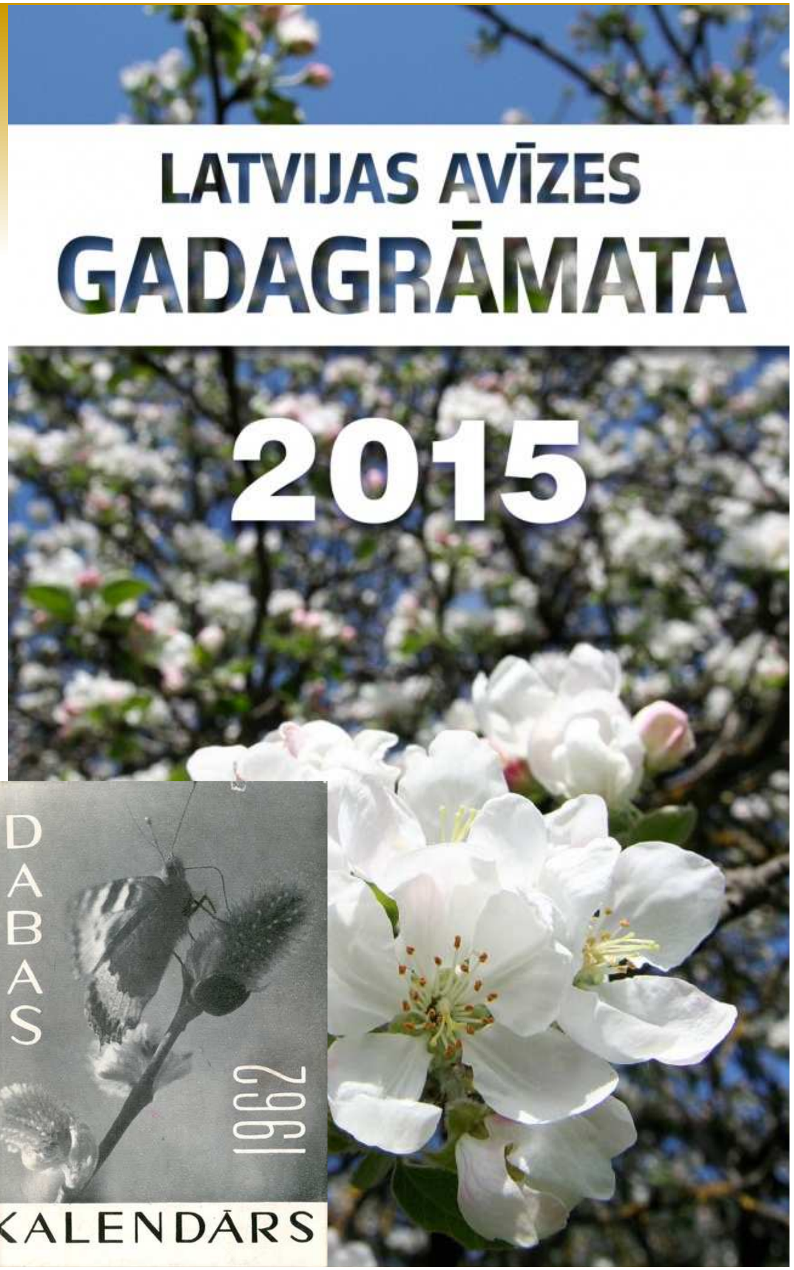
The oldest written systematic data of nature observation are found in Japan, where the imperial palace archives have preserved details of the flowering of cherry *Prunus subertilla* as an indicator of the beginning of spring since year 705

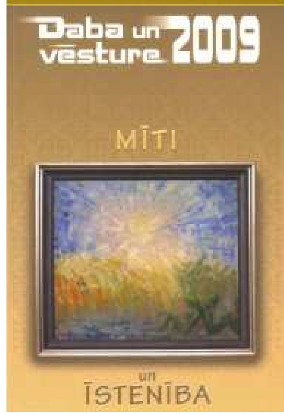
In Europe the data on *Pinot Noir* grape ripening time are reconstructed in France since year 1370

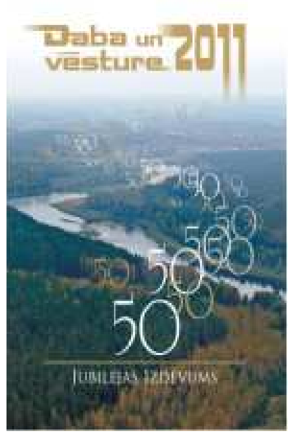
In Latvia the first written nature observations are dated since 1822, but systematic observations have been made since 1927

Annually (with interruptions during the World War II) natural observations were published in books and calendars, e.g., «Nature and History» until 2013; from 2014 «Latvia Newspaper's Yearbook»

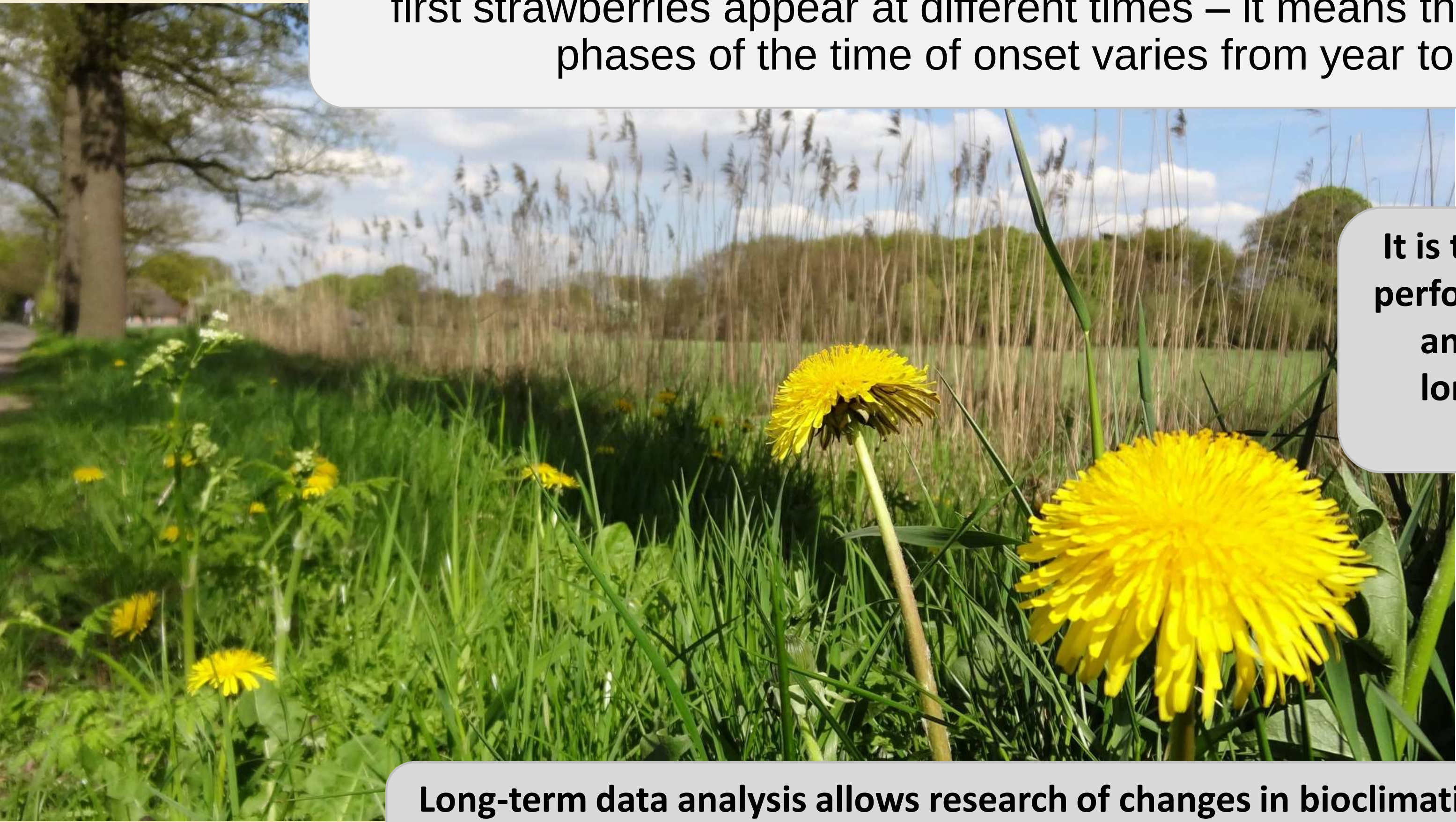








Everyone has noticed that every year the leaf unfolding, flowering or the first strawberries appear at different times – it means that phenologic phases of the time of onset varies from year to year



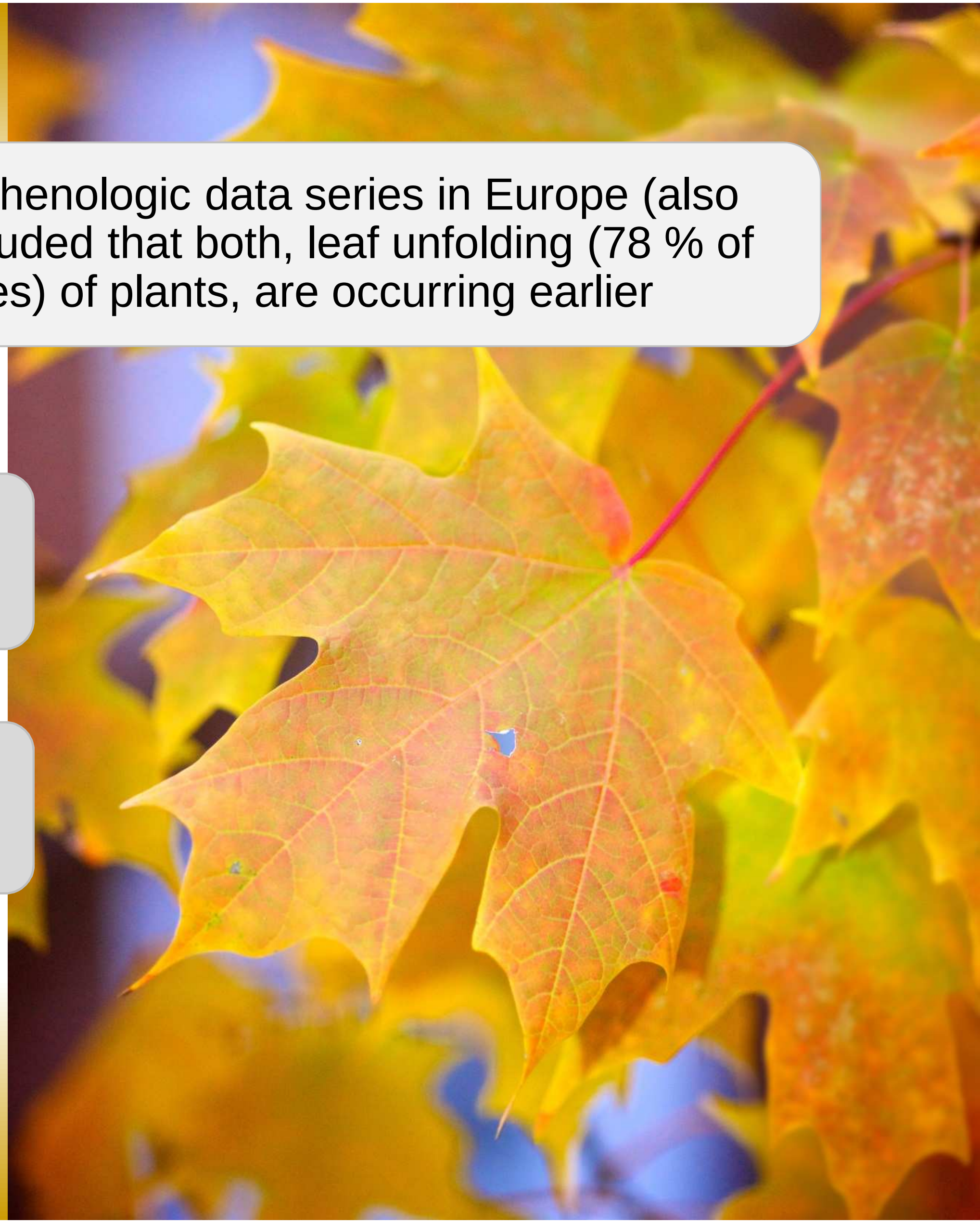
It is therefore particularly important to perform a long-term data collection and analysis including at least 30 years long data sets or a selected survey period (*e.g.*, years 1981-2010)

Long-term data analysis allows research of changes in bioclimatic parameters, which can be further practically used in forestry, agriculture and other sectors

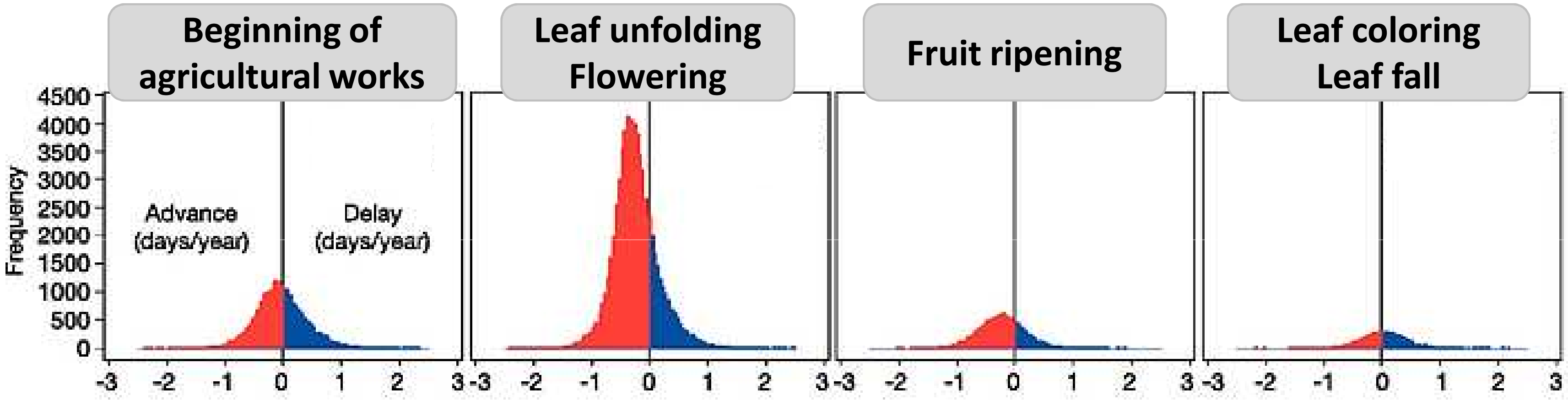
After analyzing more than 100,000 of phenologic data series in Europe (also including data from Latvia), it was concluded that both, leaf unfolding (78 % of cases) and flowering (31 % of cases) of plants, are occurring earlier

By contrast, 48 % of the autumn data series showed a positive trend, i.e., autumn begins later, and 52 % revealed a negative trend (leaf fall occurs later)

Fruit ripening in selected survey period started earlier, but it can be attributed mainly to agricultural crops rather than to wild plants



Changes in phenologic phases in Europe during the time period 1971-2000



In overall, phenologic spring and summer in a survey period (1971-2000) in Europe started by 2.5 days earlier in a decade

The study involved data from 21 country about more than 542 plant species

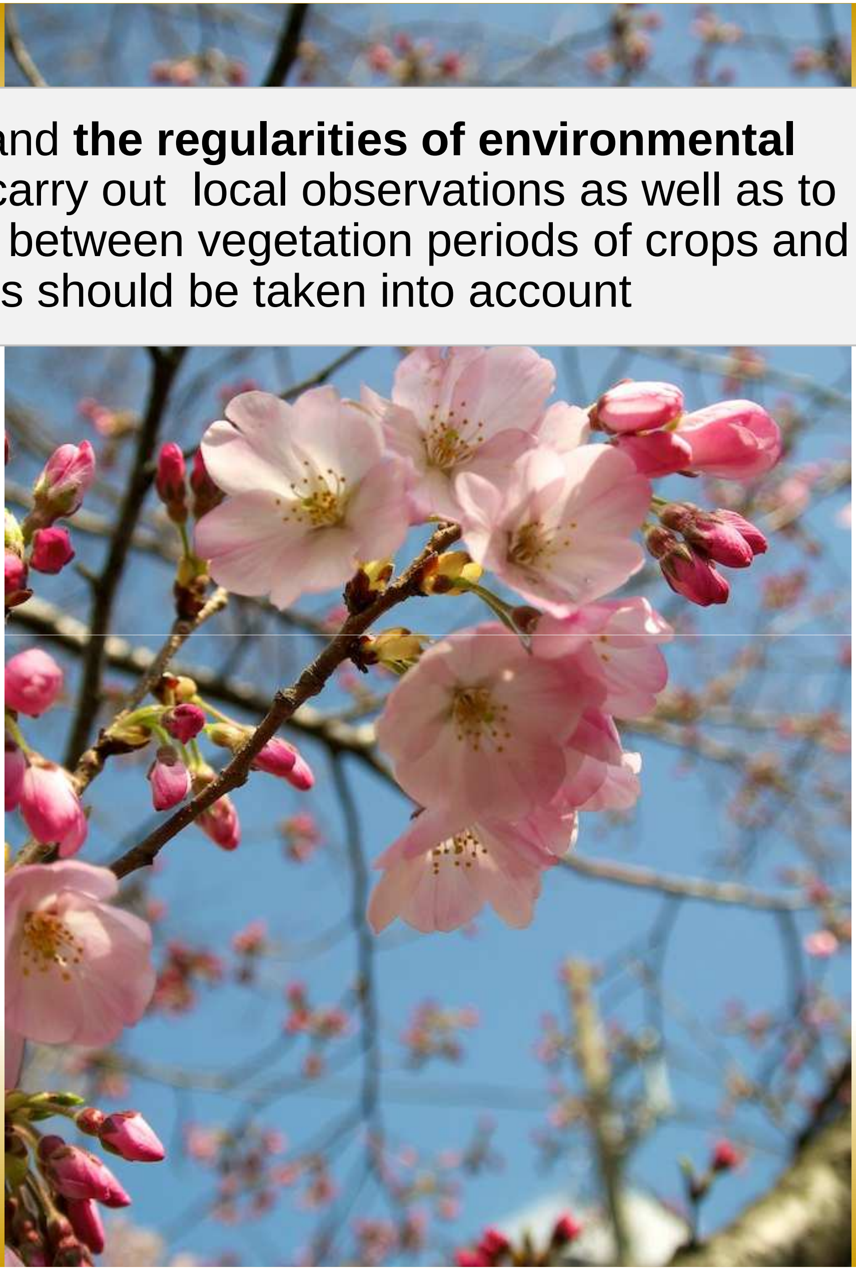
Studies reveal that change of air temperature is the main contributing factor, i.e., increase of air temperature by 1 ^{o}C induces beginning of spring-summer phase by 2.5 days earlier, but autumn phase – by 1 day later

In addition, early spring phases are more sensitive to changes of temperature

Between leaf coloring, leaf fall time beginning and air temperature a significant relationship was not detected

It means that the autumn phases are related to other limiting factors which have not yet been fully explored

Research at global or European level helps to understand **the regularities of environmental rhythms and influencing factors**, but it is important to carry out local observations as well as to compare different species, because there are distinctions between vegetation periods of crops and wild plants; in addition, geographical differences should be taken into account



Beginning of vegetation period of fruit trees in Germany has changed – it starts by about 2.3 days earlier in a decade (cherry flowering – 2 days earlier, apple flowering – 2.2 days earlier)

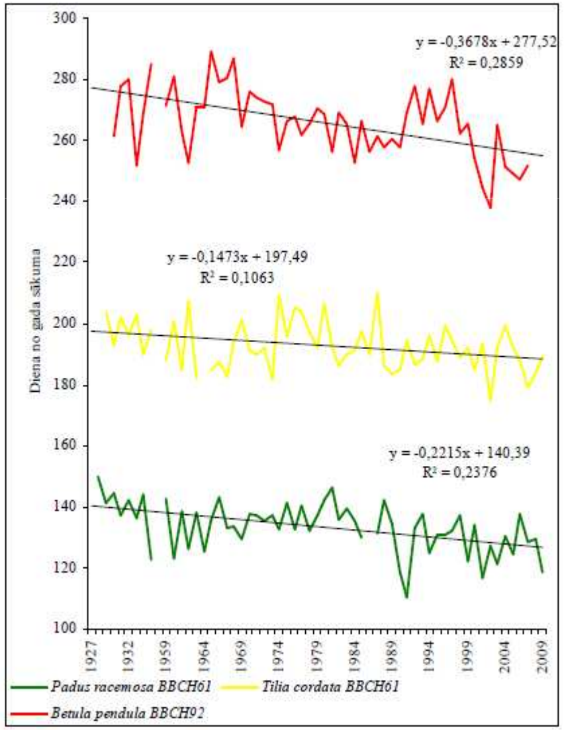
In France apricot and peach flowering time in the last 30 years changed by about 1-3 weeks

Time of sowing (sēja) or planting (stādīšana) has changed as well as for cereals, as other crops

In Finland potatoes are planted by about 5 days earlier, in Germany - corn, sugar beet by 10 days earlier, in France sowing of corn starts by up to 20 days earlier

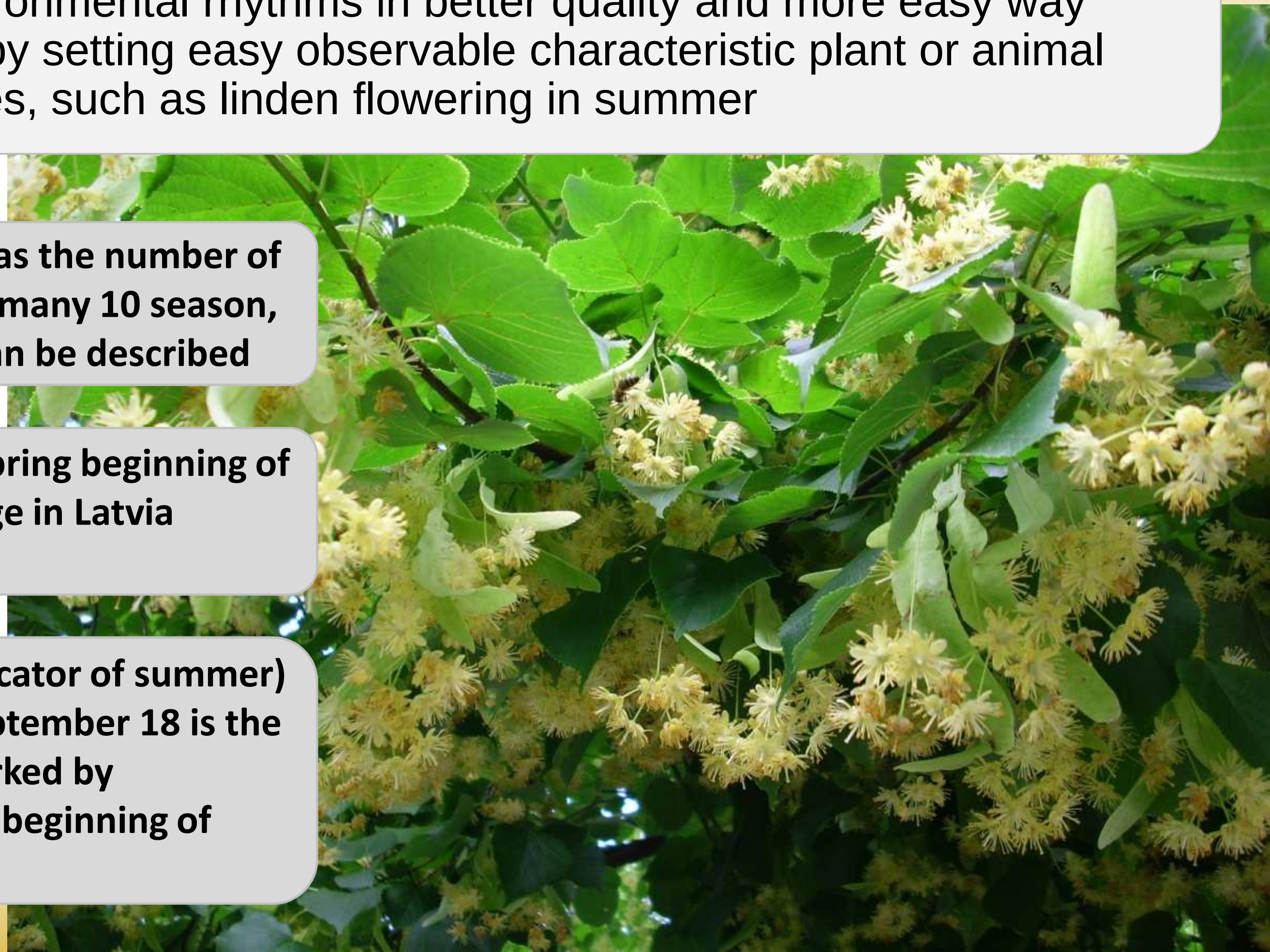
Although the number of observations and location of observation points in Latvia varies from year to year, which complicates the analysis of the data, in general bioclimatic trend in Latvia coincides with European and world data: **phenological springs and summers are tended to start earlier**

In contrast to the trends observed in Europe, phenological autumn in some places of Latvia and Lithuania begins earlier (leaf coloring and leaf fall starts earlier), or change in trend is neutral



Bird cherry *Padus racemosa* and lime-tree *Tilia cordata* flowering (BBCH61) and birch *Betula pendula* leaf colouring (BBCH92) long-term changes (1927-1939 and 1959-2007) in Latvia

In order to characterize annual environmental rhythms in better quality and more easy way **phenological seasons** are divided by setting easy observable characteristic plant or animal development phases, such as linden flowering in summer



Species-indicators in different countries, as well as the number of different seasons is variable, for example, in Germany 10 season, but in Latvian up to 12 phenological seasons can be described

As the most common indicator of phenological spring beginning of hazel flowering is assumed, that on average in Latvia occurs on March 24

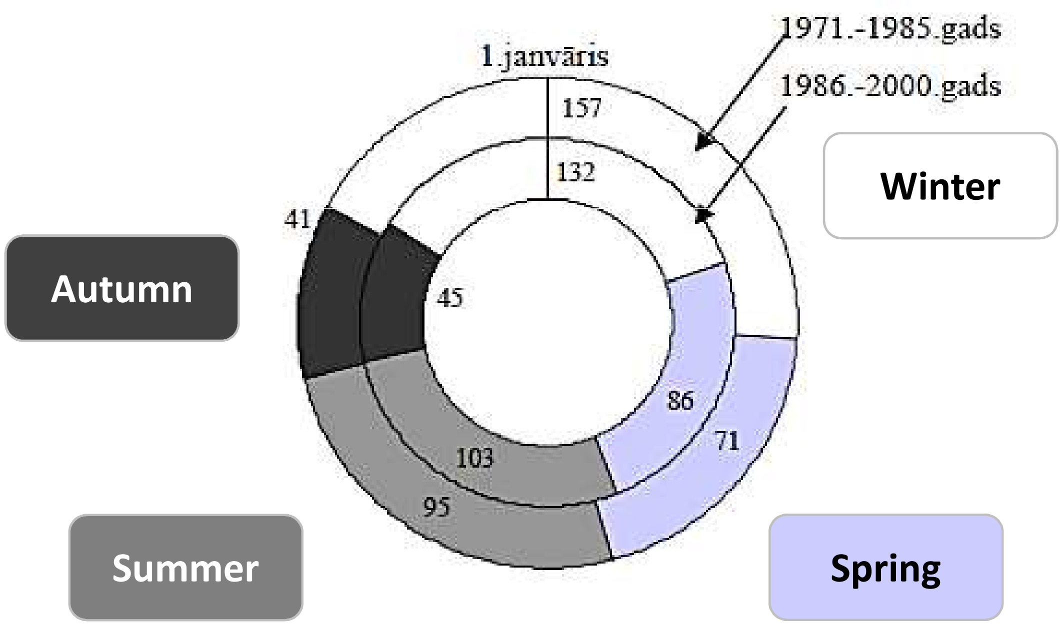
But forest raspberry flowering (phenological indicator of summer) in Latvia on average occurs on June 11, while September 18 is the beginning of phenological autumn marked by birch leaf coloring; the first snow means the beginning of phenological winter

Hazel Flower Female

Male catkins (common hazel)

Raspberry

Beginning of phenological seasons during a calendar year and changes in length (days) of phenological season length in Latvia



During the survey period (1971-2000) beginning and duration of phenological seasons have substantially changed

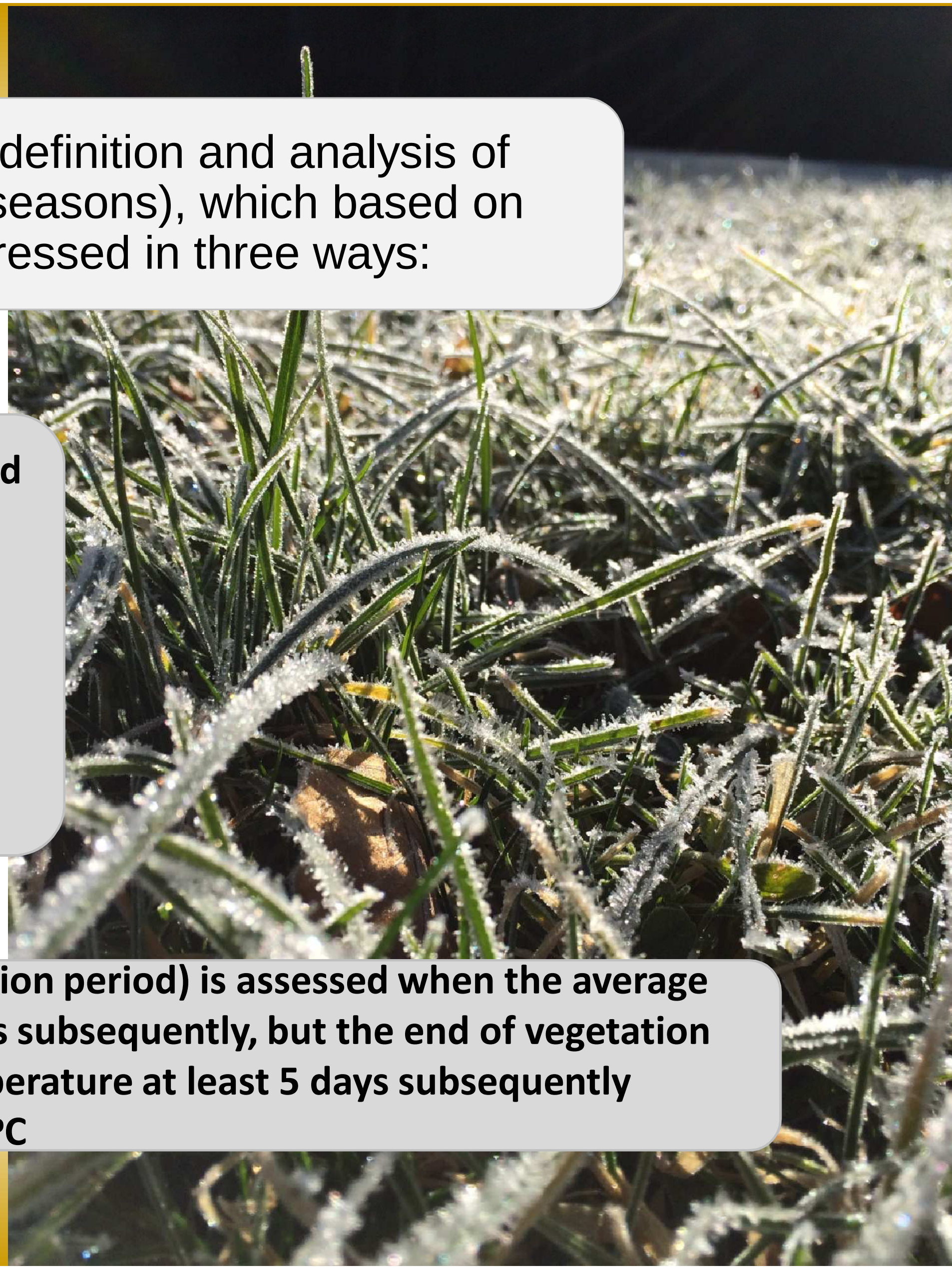
<u>Indicators of phenological seasons</u>:

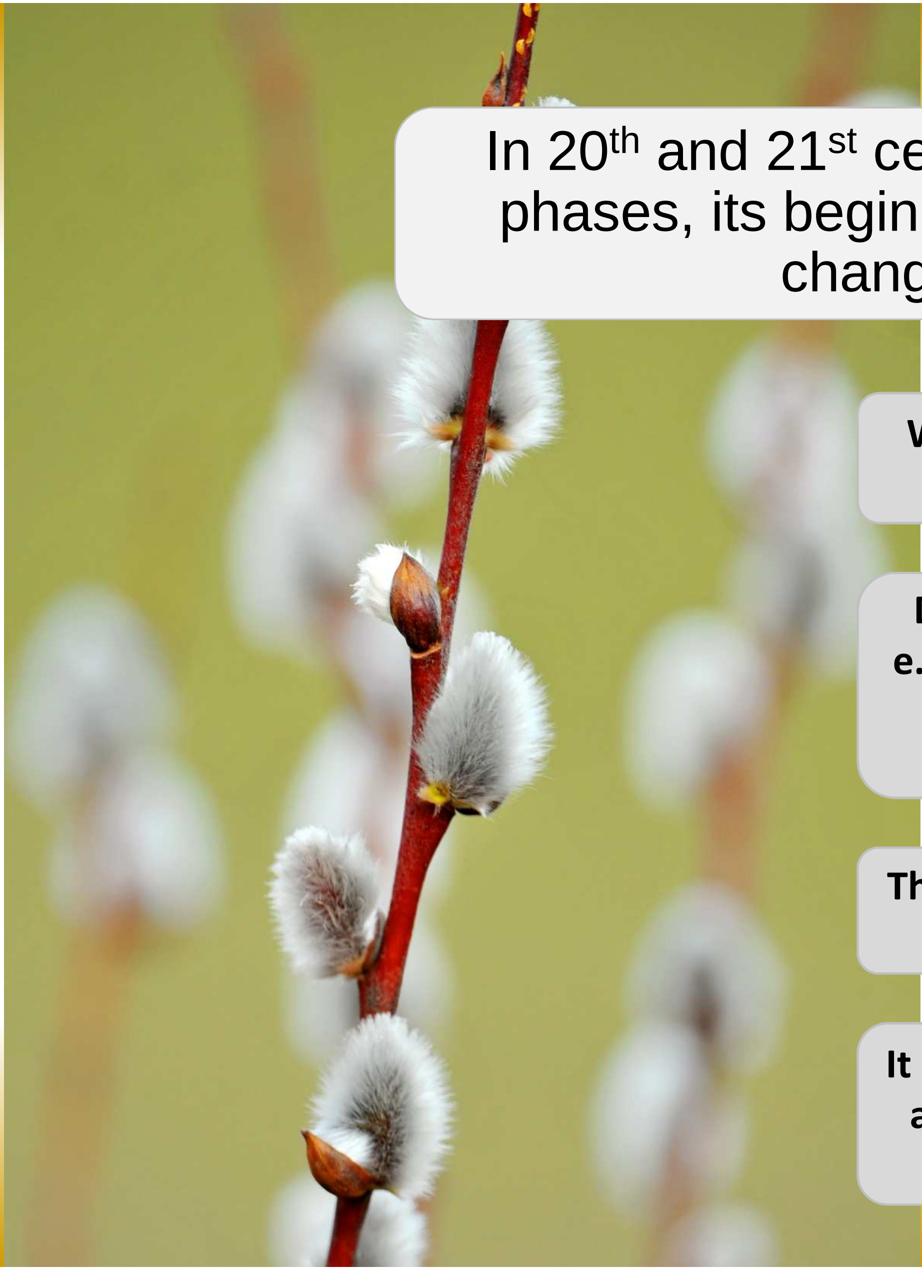
- **Spring – beginning of hazel flowering**
- **Summer – beginning of wild raspberry flowering**
- **Autumn – colouring of birch leaf**
- **Winter – the first snow**

Agriculture and forestry demands definition and analysis of vegetation periods (plant growing seasons), which based on scientific literature can be expressed in three ways:

1) **Period or number of days between the last frost in spring and the first frost in fall (used mainly in North America)**
2) **Climatic growing season (vegetation period)**
3) **Phenological growing season as a period between the leaf unfolding deciduous trees and leaf colouring or from other sources – a period between bud formation and leaf fall or a period between leaf unfolding and leaf fall**

In Latvia the beginning of a growing season (vegetation period) is assessed when the average daily temperature is higher than $+5\ ^{o}C$ at least 5 days subsequently, but the end of vegetation season is assessed when the average daily temperature at least 5 days subsequently is below, $+5\ ^{o}C$





In 20th and 21st centuries time of phenological phases, its beginning, duration and end, has changed substantially

Worldwide average phenological spring occurs by 8 days earlier, but the vegetation period is prolonged by up to 12 days

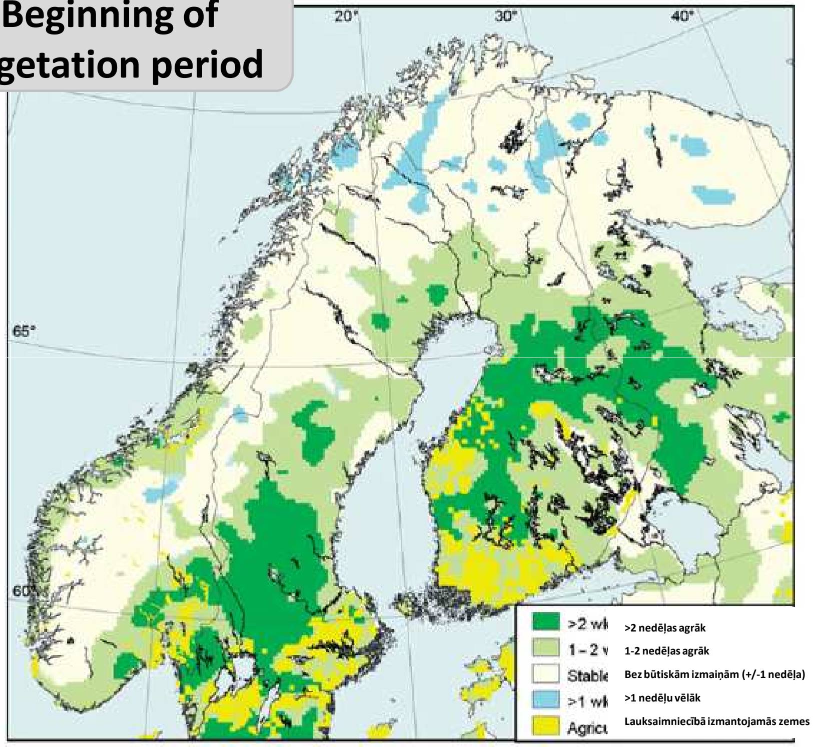
Differences vary depending on the location of observation site, e.g., analysis of the data from phenological gardens reveal that in overall the growing season is prolonged by about 10.5 days, i.e., by +3.5 days a decade

The greatest changes are observed in Central Europe, less in north Scandinavia south-east Europe

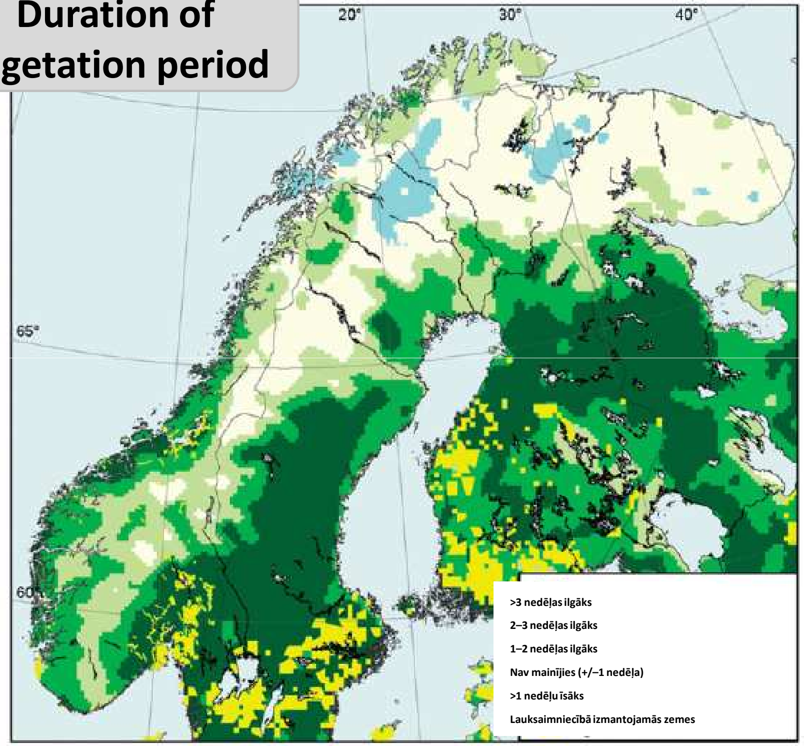
It is estimated that phenologicals seasons in Europe «are moving» at a speed of 44 km per day from south to north and at a speed of 200 km per day from west to east

Changes of beginning and duration of vegetation period during the time period 1982-2006 in north Europe

Beginning of vegetation period



Duration of vegetation period

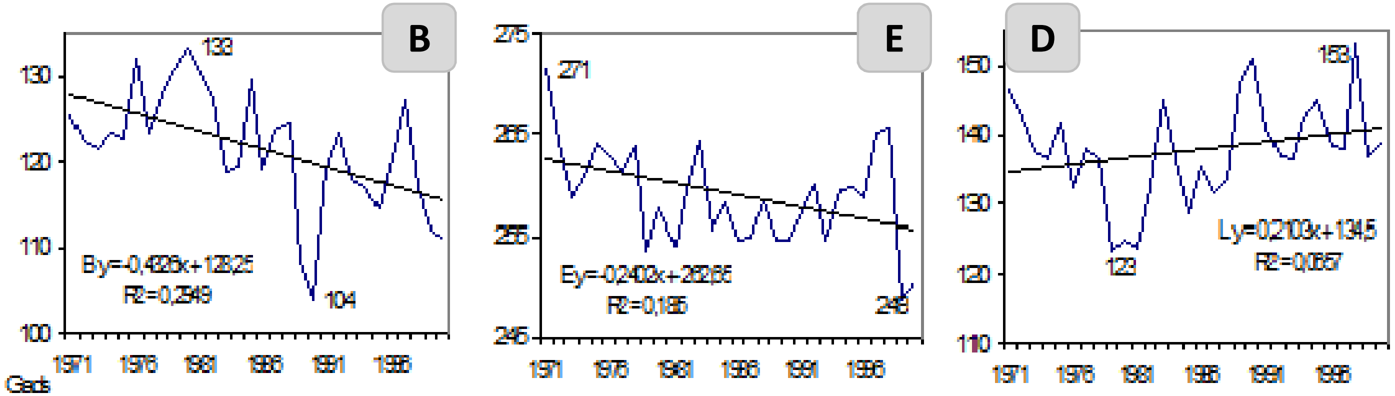


Analysis of satellite images reveals that in north Europe the majority of phenological springs occur by 2 weeks earlier (in some places even more than 2 weeks earlier), while phenological autumns occur by 2-4 weeks later, prolonging duration of vegetation period by 2 up to more than 4 weeks

The average length of vegetation season (the period between the leaf unfolding and leaf yellowing) for birch has changed on average by a 7-day interval, mainly due to the earlier beginning of spring phase

Beginning of vegetation season mainly depends on the air temperature changes

Whereas, the end of vegetation season is influenced by other factors or combination of factors (duration of day light time (photoperiod), moisture conditions, extreme temperatures, marine impacts etc.) which are not clear precisely



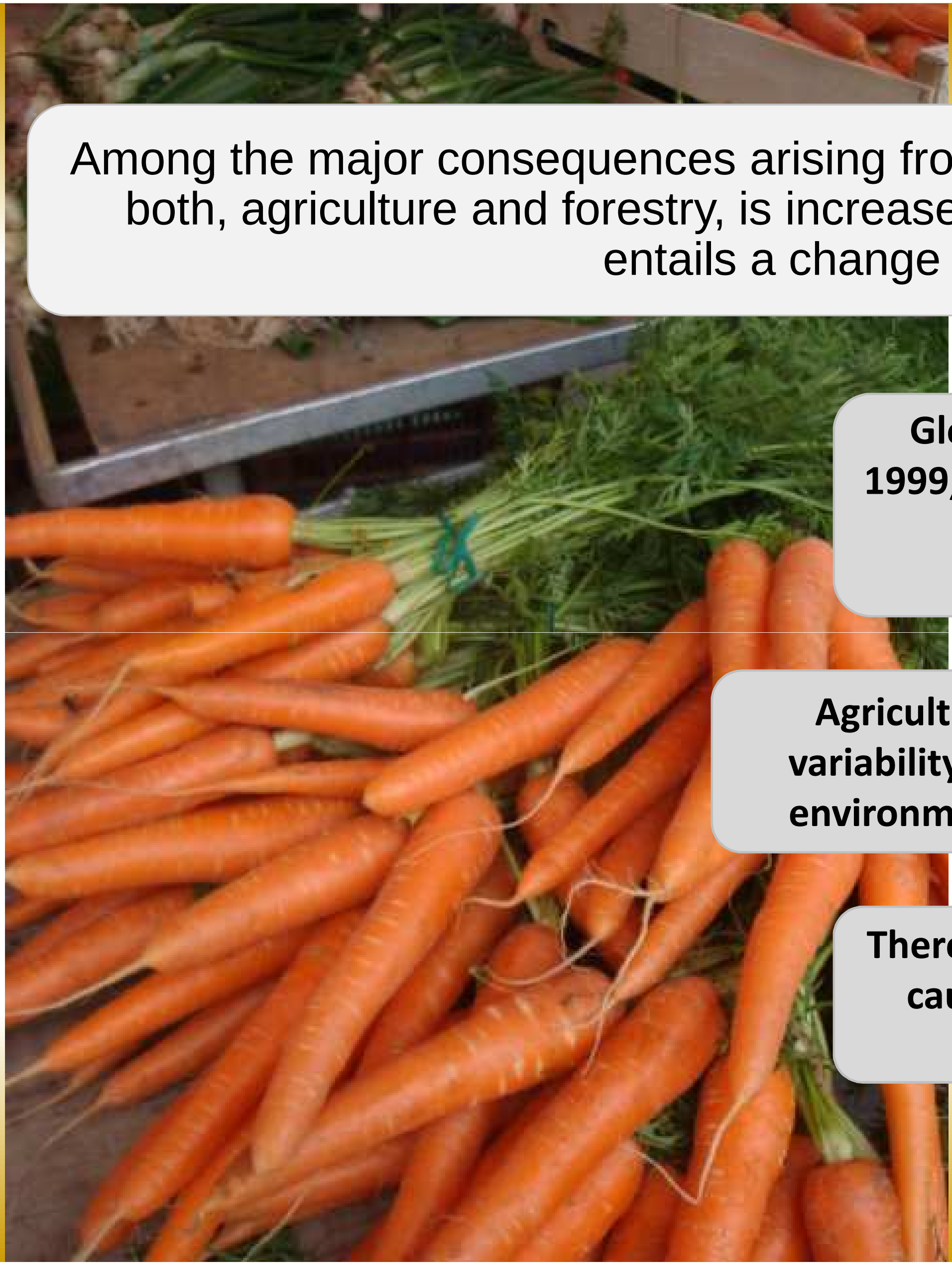
Changes of beginning (B), end (E) and duration (D) of vegetation season for *birch Betula pendula* (1971-2000) in Latvia and Lithuania (on the y axis: the day from the beginning of year)

IMPACT OF CLIMATE CHANGE ON AGRICULTURE

Classically, nature observations have been used in agriculture and forestry, thus the bio-climatic research which are especially important for these sectors as well as modeled predictions can be used **for future risk assessment and example analysis of opportunities and adaptation**

The role of nature observation is much broader - they help to explain the complex ecological dynamics (influencing factors and environmental impact), as well as are used in studies of global climate change and biogeochemical cycles (CO_2 cycle, nutrient cycles, the hydrological cycle) and other studies (ecosystem productivity, species and inter-population dynamics)

Climate change impacts can not be assessed not as bad or good as it brings both, benefits and losses - in the case of agriculture and forestry the changes has to be assessed as a complex by critical assessment of influencing factors because during the last 100 years significant changes have been attributed to the exploitation of forests and rural processing technologies, public policy, land use change etc.



Among the major consequences arising from the prolongation of vegetation season influencing both, agriculture and forestry, is increase in **CO_2 concentrations in the atmosphere** that entails a change in the primary productivity

Global primary production (net) during the period from 1982 to 1999, based on the satellite analysis, has revealed an increase by 6 % - higher increase was observed for tropical ecosystems, but in Eurasia – even up to 12 %

Agriculture is one of the most sensitive economic sectors to climate variability because it reacts immediately to the change of weather and environmental conditions, in addition, it is the most difficult to predict

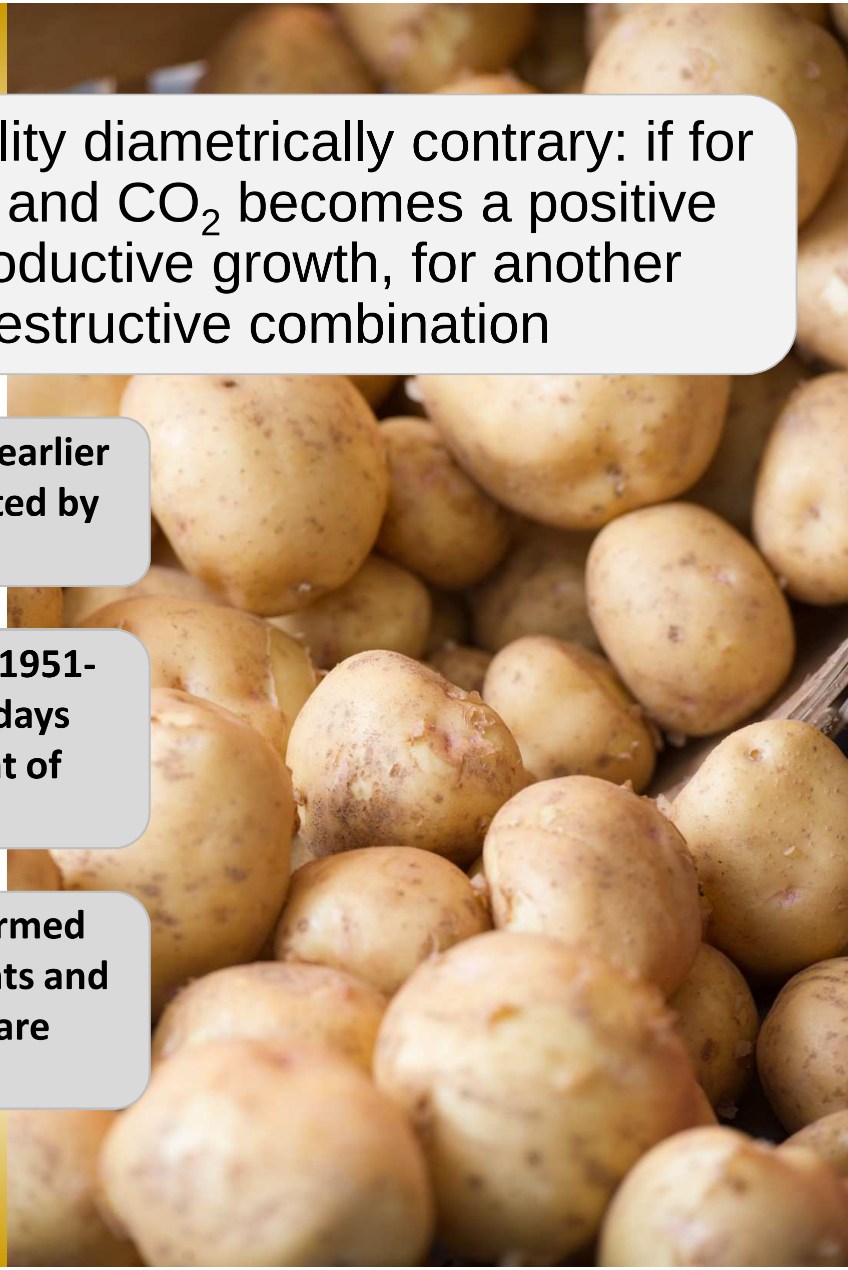
Therefore, future prognosis for agriculture are carried out with great cautions because agriculture as an economical sector is affected by a complex set of influencing factors

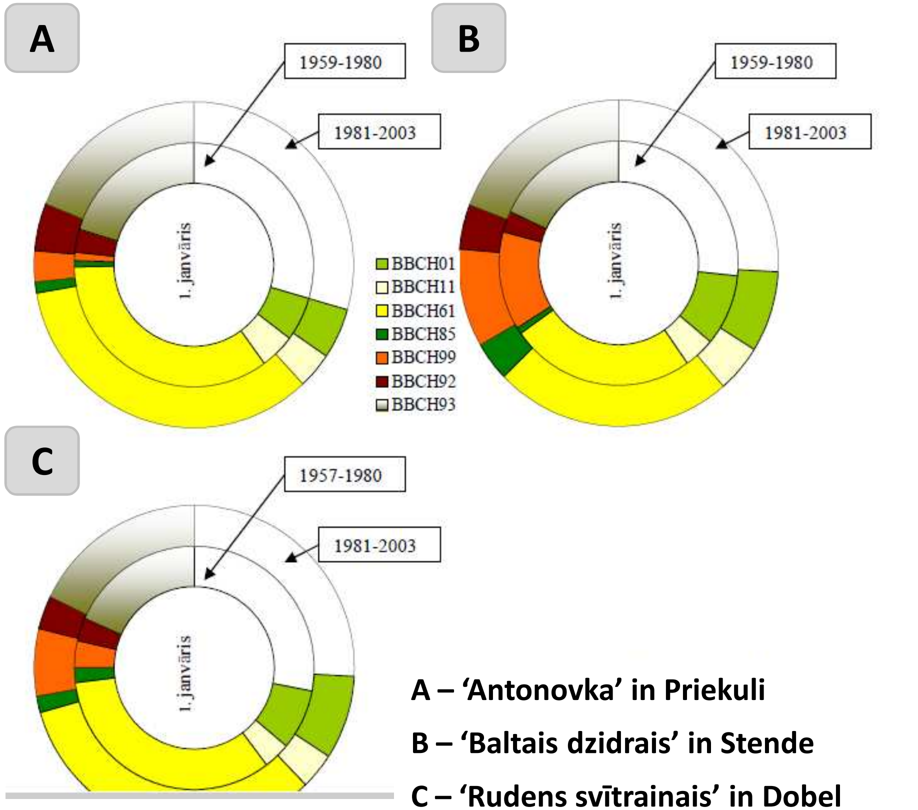
Many of crop species react to climate variability diametrically contrary: if for one of species increase of air temperature and CO_2 becomes a positive factor inducing earlier, faster and more productive growth, for another species the same factors can be a destructive combination

Studies reveal that species which are pollinated by insects, bloom earlier than wind-pollinated plants, as well as wild plants are more affected by climate variability than cultivated crops

For example, a study in Germany revealed that during the period 1951-2004 wild plant development stages intervened from 4.4 to 7.1 days earlier than in previous decade, but changes in the development of cultivated crops are not so rapid (only 2.1 day per decade)

Data obtained at the agro-meteorological stations of Latvia confirmed that for most of the studied crop species (cereals, potatoes, currants and apple trees) phenological phase starts earlier, but the changes are not as significant as for wild plants





A – ‘Antonovka’ in Priekuli

B – ‘Baltais dzidrais’ in Stende

C – ‘Rudens svītrainais’ in Dobel

Changes of phenological phases for varieties of apple trees *Malus domestica*

Agro-meteorological stations indicated that apple tree *Malus domestica* bud forming occurs during 6 to 18 April (depending on a variety)

Long-term observations reveal that a tendency is neutral (beginning of bud forming does not change significantly) or negative (in Dobele, Dagda), while leaf unfolding and flowering tendency is negative in most of places (except Dagda)

Overall apple tree flowering occurs 1-3 days earlier than in previous decade – mostly earlier spring phases were detected during the 90s of the 20th century, but the latest ones – in the 70s and 80s; actually apples ripen earlier

Leaf yellowing started from 6 to 14 October, and leaf yellowing tendency in Dobele and Priekuli was neutral (phase has not changed), but in Dagda – positive, while in Stende – negative

Growth duration for apples on average is 150 days, with a tendency to be extended which is particularly explicit for 'Antonovka' variety

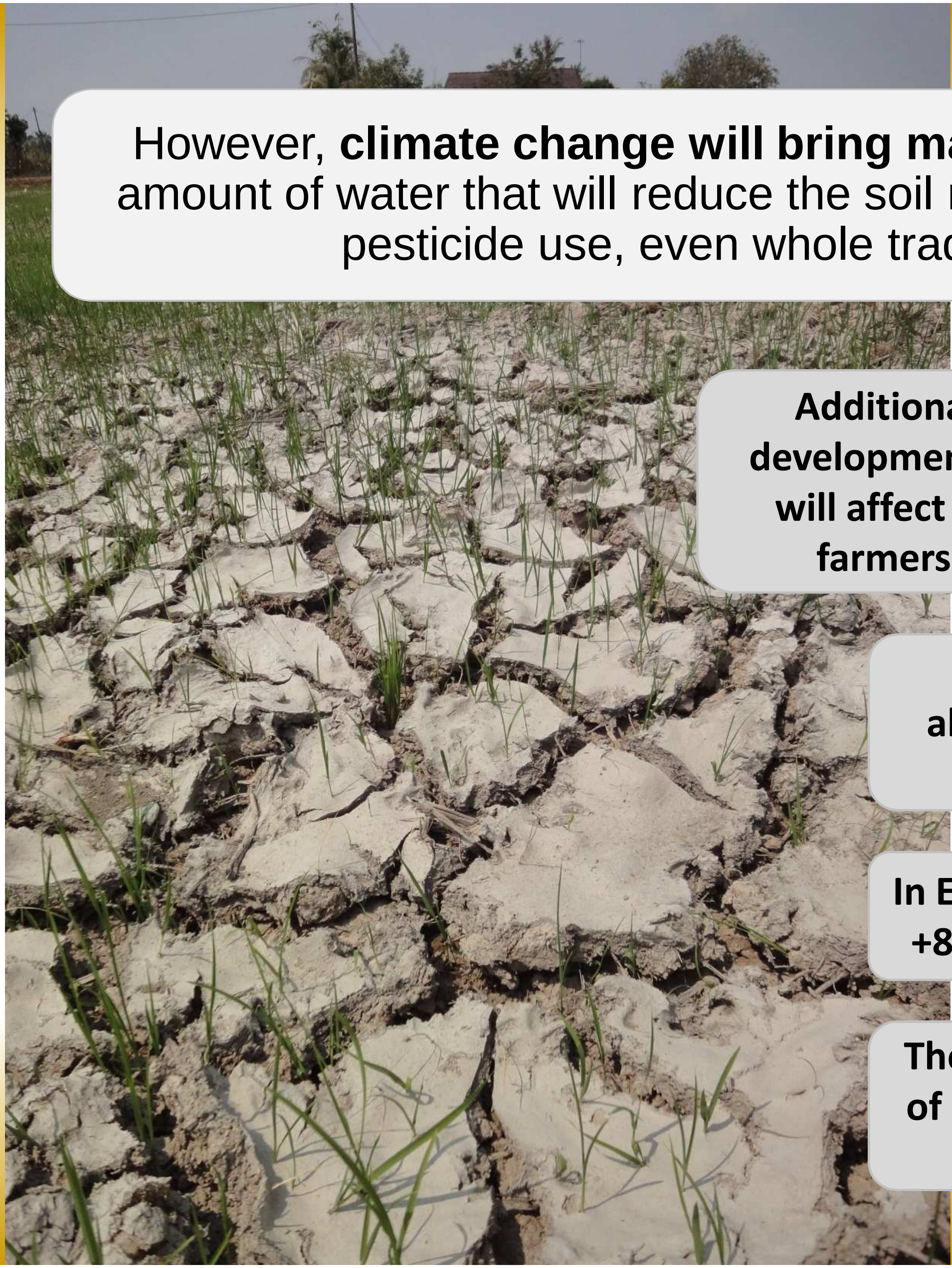
Impacts of climate change on agriculture in the future will be manifested differently in various regions of the world

Globally, crop yield of cereals – wheat, corn, barley – decreases due to increase of temperature

In southern European countries, crop yields have begun to decrease, but northern Europe crop yield of individual cereals even has increased

In Latvia farmers most of all will be affected by forecasted drought and intense precipitation

Most often, as positive effects of climate change in agriculture prolongation of the vegetation season is mentioned, as well as intensity of photosynthesis will increase, new opportunities for crop growth and productivity are foreseen for northern Europe



However, **climate change will bring many risks:** in some regions there will be insufficient amount of water that will reduce the soil moisture, crop damage will appear due to increased pesticide use, even whole traditions of regional agriculture can change

Additional warmth and moisture will serve a favorable environment for development of fungi and various pathogenic microorganisms that adversely will affect the development of plants and indirectly also human health, as farmers will have to use greater amount of plant protection products

Significant risk to farmers can be caused by late spring frosts – although generally frost-free periods will be prolonged, mostly it's due to delayed frost occurrence in autumns

In Europe, in 1992-2008, the end of frost-free periods are occurring by +8.2 days a decade, but the beginning – earlier by 3.2 days a decade

The end of late spring frosts occurs earlier, but also the development of plants in the spring starts earlier, thus there is a substantial risk of plant damage, as it was happening in 2003 in Europe

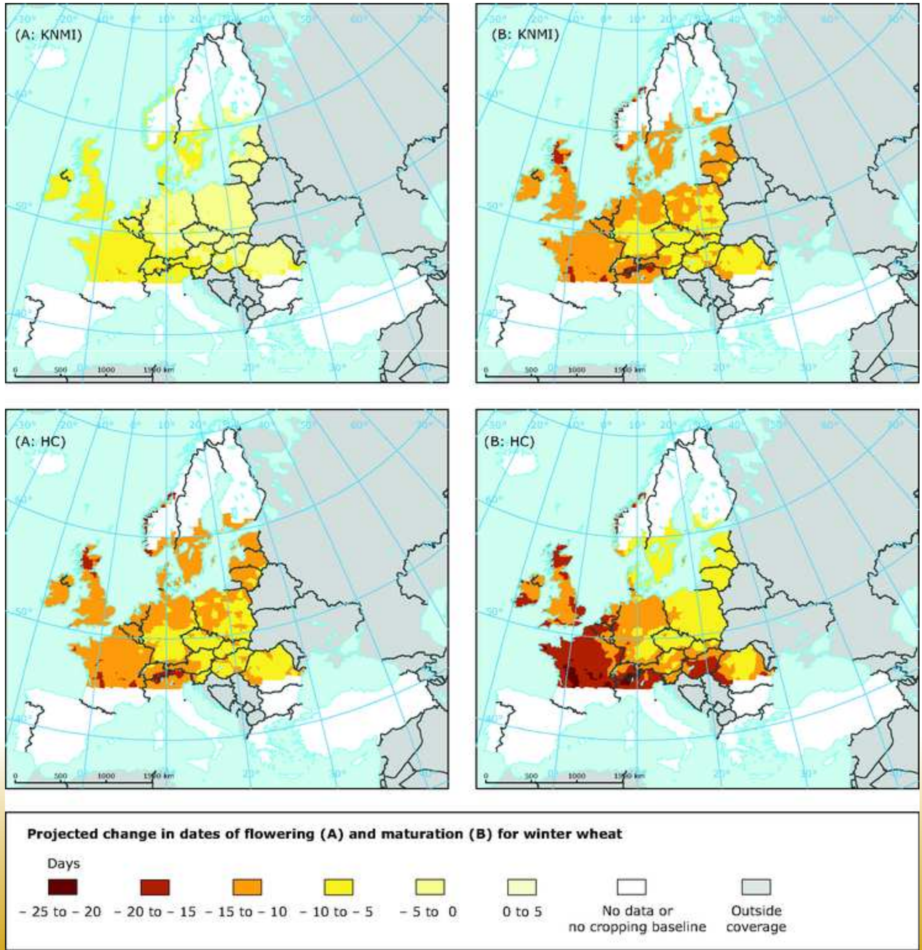
Due to unstable, non typical and difficult to forecast weather conditions farmers will not be able to predict the annual crop yields - it is a huge risk for the development planning of agricultural sector

On one hand, prolongation of vegetation season will increase crop productivity, because longer plant development cycle allows the use of maximum solar heat, water and nutrients which leads to increased crop yields

On another hand, the negative impact is that the air temperature and regime of humidity may decrease the time between the plant development cycles, for example, the time between the shooting into culm (stiebrošanās) and ears formation (vārpošanās) for cereals which can reduce crop yield

European Environment Agency and the European Commission's research centers regularly carry out future prognosis for changes in development phases of species important for agriculture

Forecasted changes (in days) for development phases of winter wheat: the beginning of flowering (A), and ripening phase (B) in period 2031-2050, according to the climate scenario A1B



It is forecasted that the flowering time of winter wheat in Europe may vary up to a month (flowering will occur earlier), but in most areas the changes of 2 weeks are predicted in comparison to period 1975-1994

Major changes of flowering are expected in coastal areas; time of winter wheat ripening phase will change more than the flowering period, i.e., it is expected that winter wheat ripening will be reached by 20 to 25 days earlier in comparison with period 1975-1994

By contrast, sowing time, flowering and ripening of spring wheat will become earlier by 1-3 weeks depending on the region

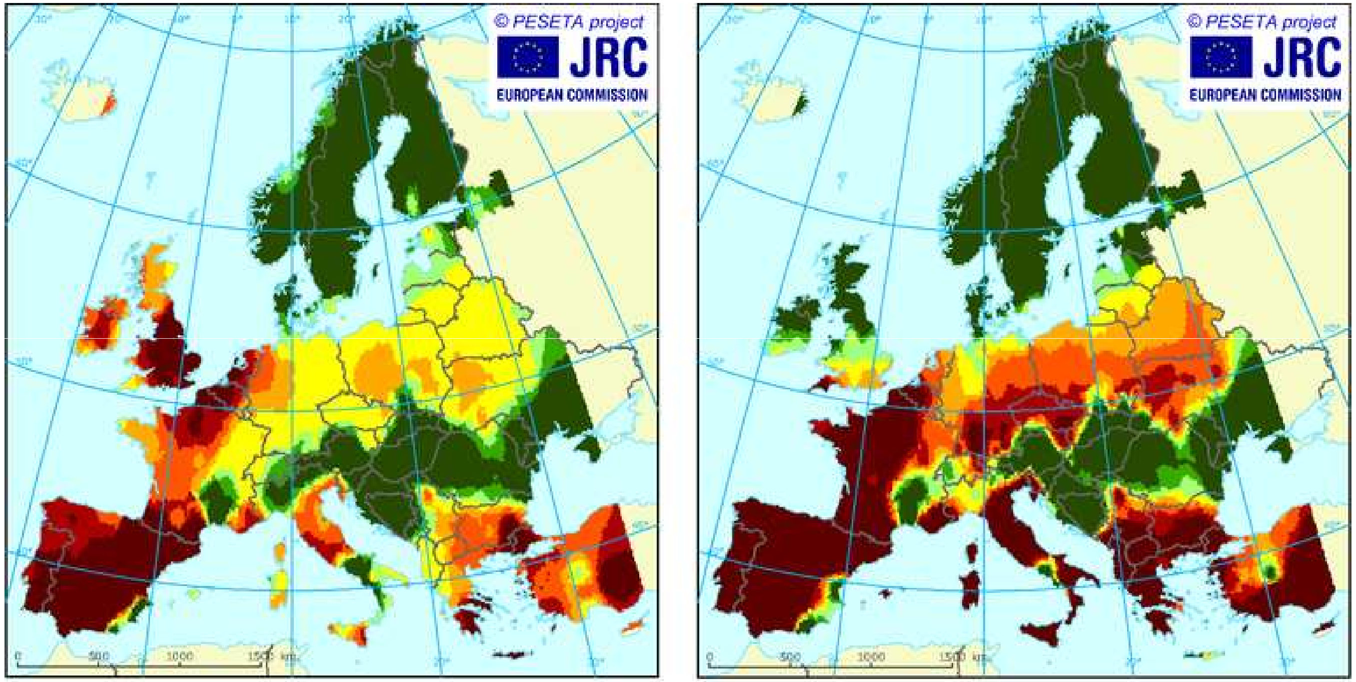
In southern Europe it is expected that crop yields will significant decrease, opposite to northern Europe for which it forecasted that in 2080 crop yields will increase even by 30 %

In northern Europe the greatest changes are expected for corn, smaller – for winter wheat

However, the modeled results are variable depending on the model used, and specific for the region - which means that prediction of crop changes is complicated

In the case of Latvia, modelled data shows a slight increase in crop yields - up to 10 %

Changes in crop yields in Europe in 2080 in relation to the reference period (1961-1990), modelling by a variety of methods

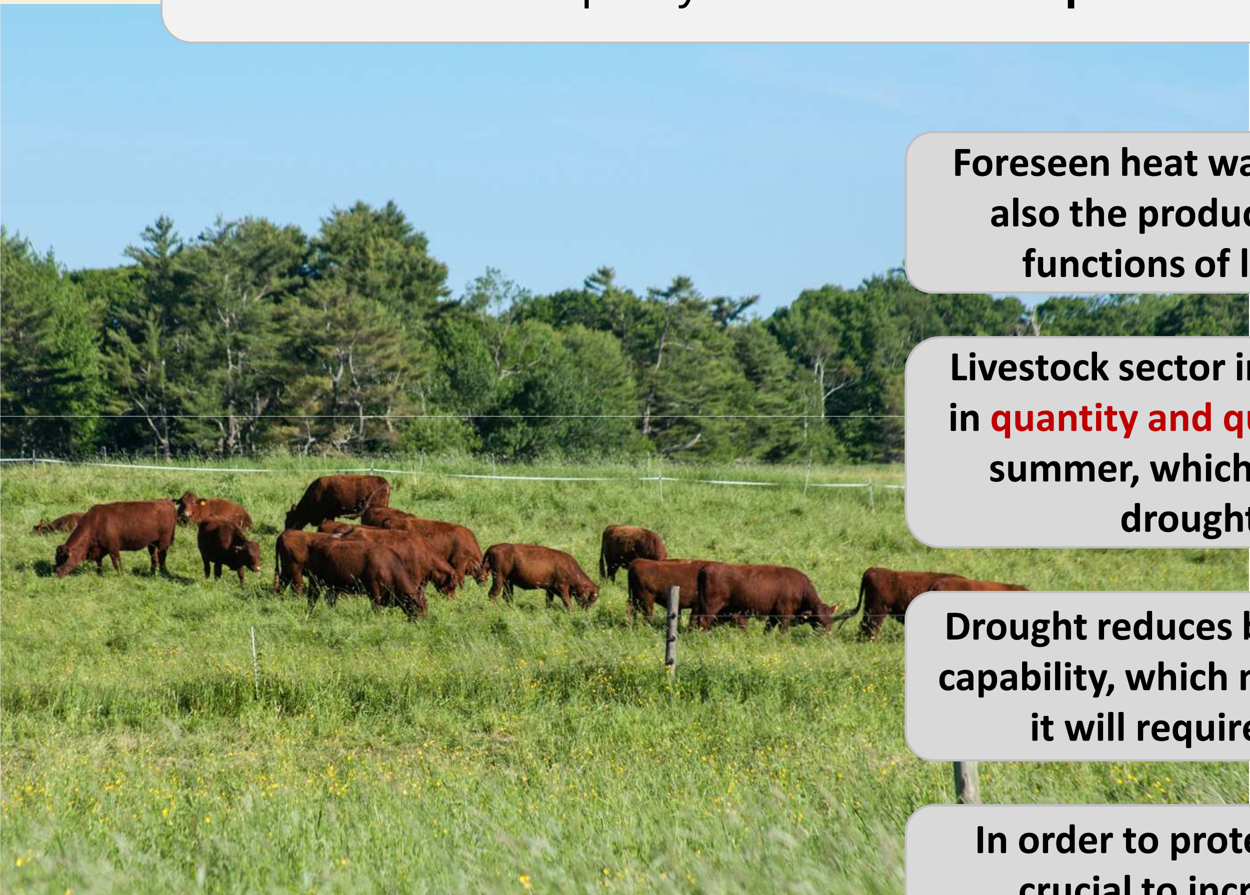


Simulated crop yield changes by 2080s relative to the period 1961–1990 under the HadCM3/HIRHAM (left) and ECHAM4/RCA3 (right) A2 scenario

Change in %

– 30 – 15 – 10 – 5 0 5 10 15 30

Air temperature and level of CO_2 will significantly change the composition of crops and their quality as well as the **impact on livestock sector** will arise

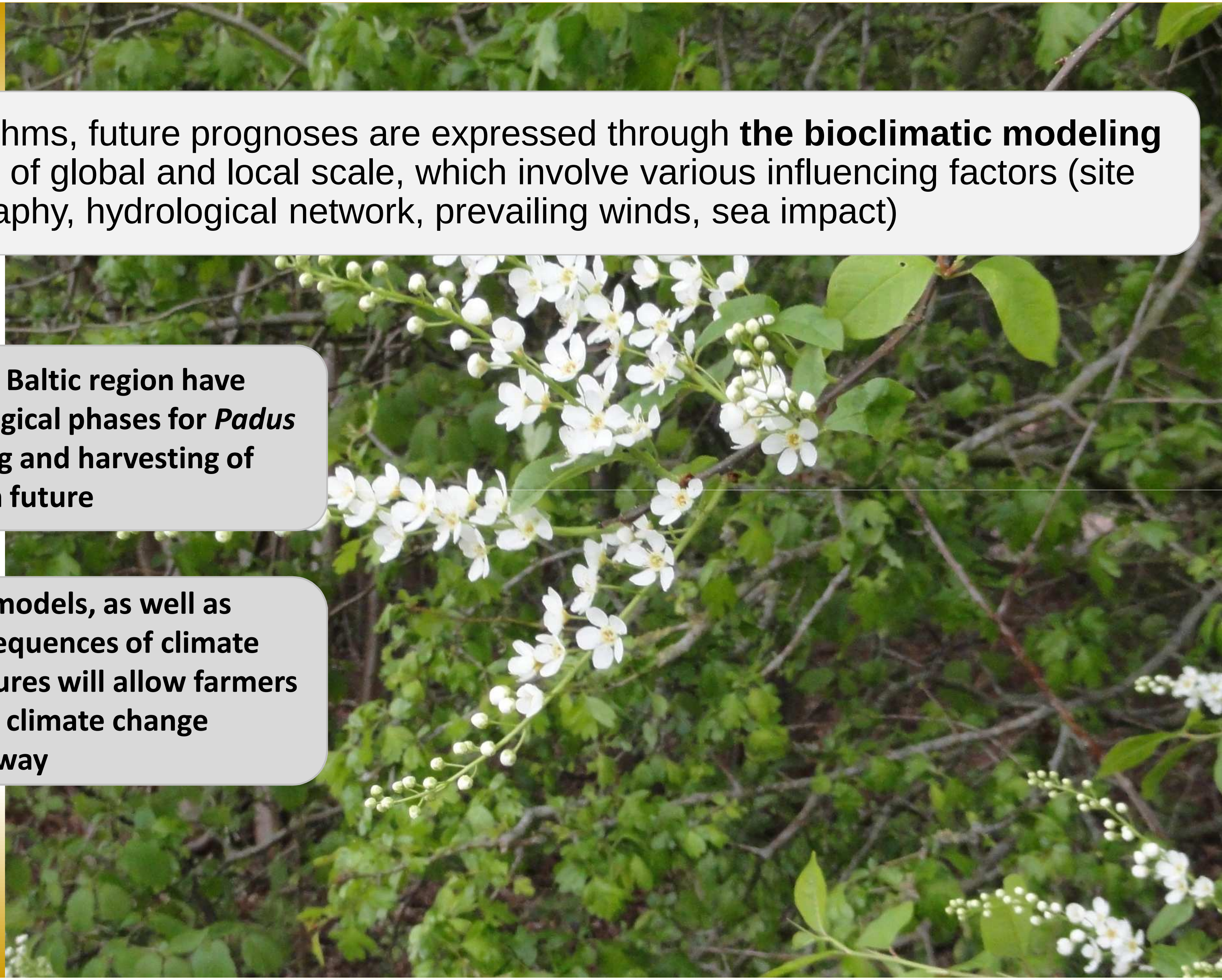


Foreseen heat waves in summers will affect not only human life, but also the productivity of livestock sector, milk yield, reproductive functions of livestock, as well as the ability to resist diseases

Livestock sector in the future will be particularly affected by changes in quantity and quality of grasslands – unusually high temperature in summer, which is expected in Europe (also in Latvia), can induce drought that adversely affect the growth of grass

Drought reduces both, plant natural ability to resist pests and growth capability, which means that the value of grasslands will decrease and it will require additional resources to provide livestock feed

In order to protect drought-weakened plants from pests, it will be crucial to increase plant protection measures, which, in turn, will increase the total costs

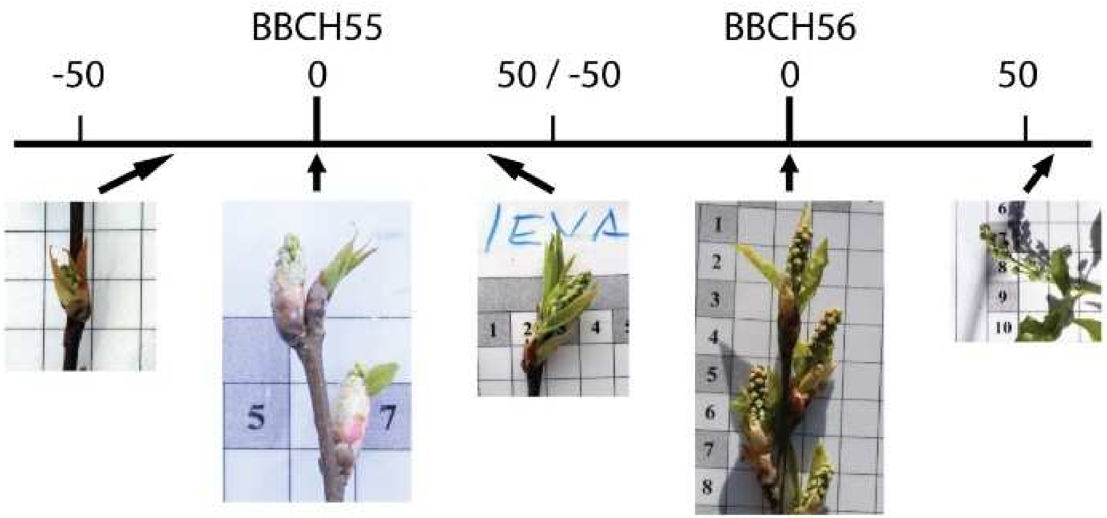


In studies of nature rhythms, future prognoses are expressed through **the bioclimatic modeling** by developing models of global and local scale, which involve various influencing factors (site topography, hydrological network, prevailing winds, sea impact)

Territory of Latvia and the Baltic region have developed models of phenological phases for *Padus racemosa* and for flowering and harvesting of strawberries in future

Forecasts in the form of models, as well as knowledge about the consequences of climate change and undertaken measures will allow farmers and foresters to exploit climate change in a better way

In 2014, an attempt was performed to predict the phenological phases of wild plants of the Baltic Sea region countries



***Padus racemosa* development phases expressed as BBCH codes:**

- Each numerical code characterizes a phase, e.g., BBCH55 means phase of visible buds
- Each phase was expressed as a percentage between the current and the next phase, e.g., in the central picture reveals visible 50 % of the phase BBCH55

The study was based on a data derived by voluntary observers, as well as the field research was carried out by photographing *prunus padus* development phases after every 30 km

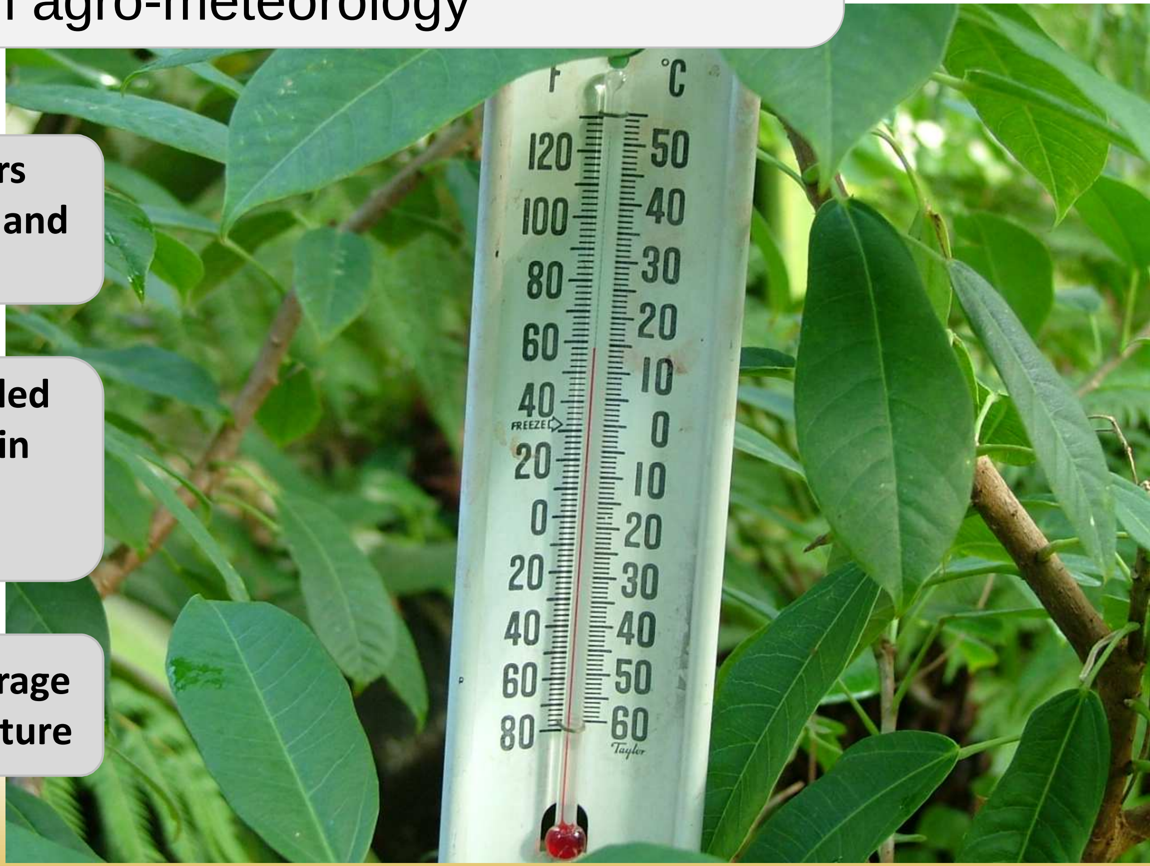
For data analysis more than 200 points of observations were used; photos were processed, describing *prunus padus* development phases

"Degree day growth model" is the simplest of phenological model types – the model is based on the widely used approach of degree days in agro-meteorology

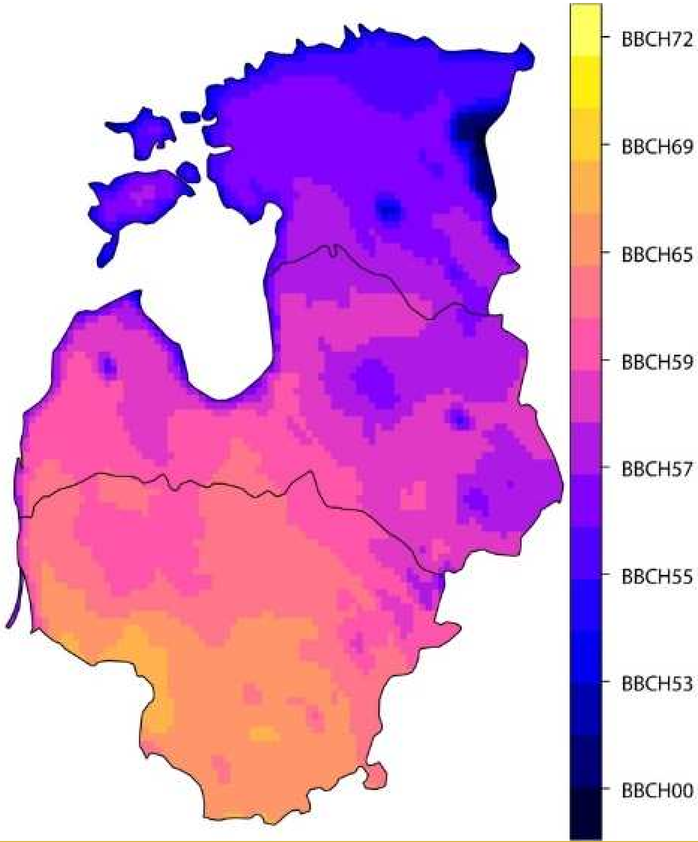
The model assumes that the plant development occurs when the air temperature exceeds a certain base value, and as it is warmer, as plants are growing faster

Temperature which exceed the base temperature is called the active temperature - it is assumed that for a certain development phase achievement a certain sum of active temperatures is required

Sum of active temperatures is obtained by counting average temperature of each day that exceeds the base temperature



By using long-term phenological and meteorological observations, it is possible to calculate the **specific base temperature for each plant species and sum of degree days** that is needed to achieve a certain stage of development



Results of the model reveal that in southern Lithuania it is expected the phase BBCH69 that is the end of the flowering stage, while in northern Estonia near Peipsi lake at the same time only bud development stage will be ongoing

Phenological models as the output data are used for weather forecasts, obtained from regional atmospheric research models

***Padus racemosa* development phases in April 30, 2014 (modelled results)**

The color scale marks the development progress or phases:

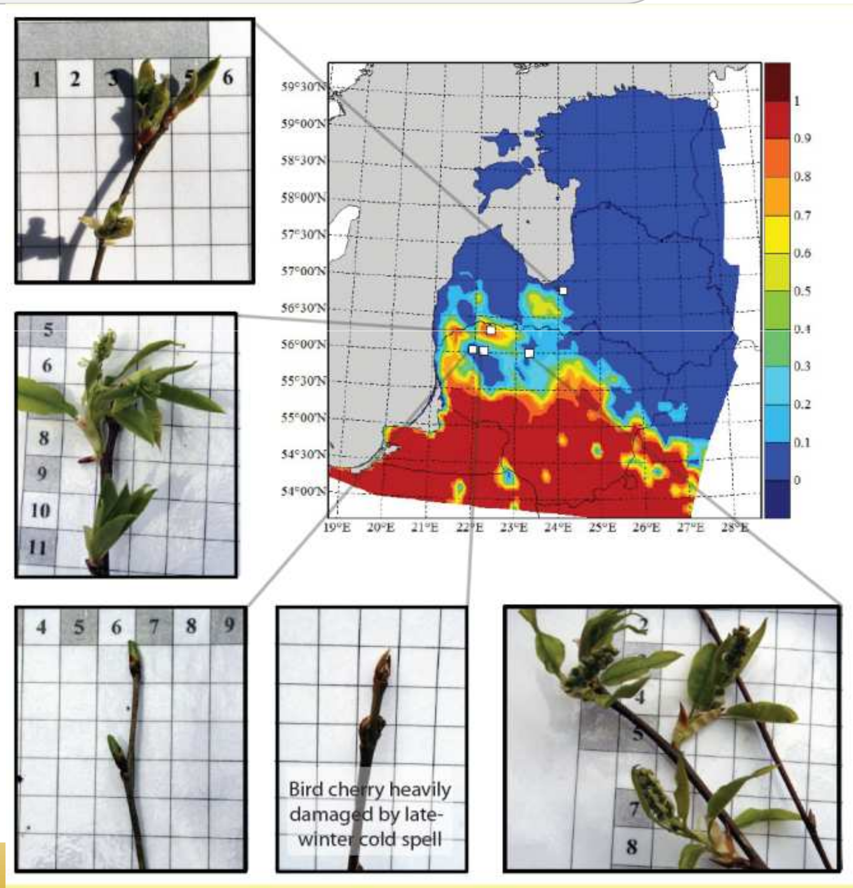
- BBCH00 – dormant buds
- BBCH10 – beginning of leaf unfolding
- BBCH5X – various development of leaf
- BBCH60-69 – flowering phase

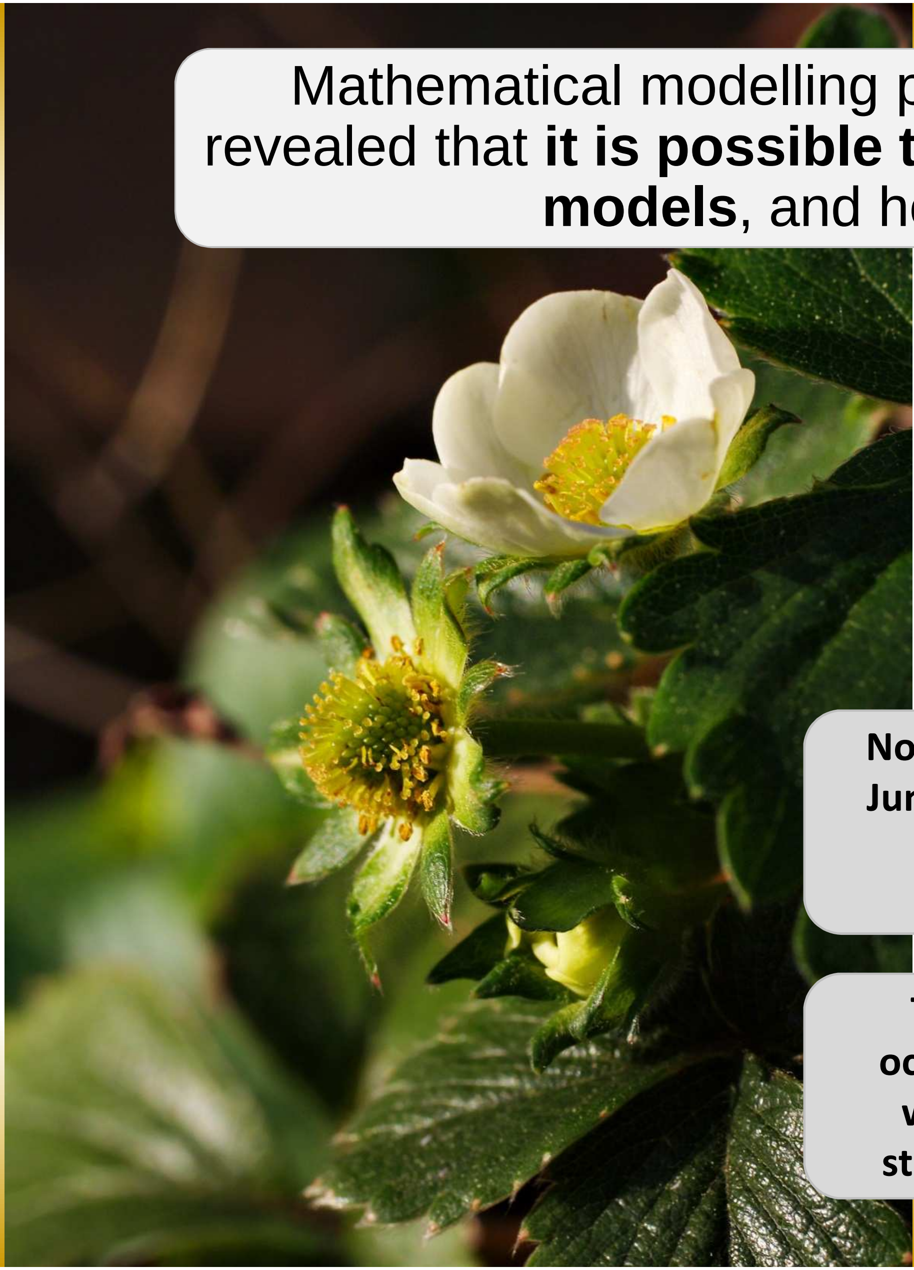
Comparison of the modelled data and the actual field observations in Baltic countries, in spring of 2014, for *Padus racemosa* leaf unfolding phase

In case of 2014, the modelled data were behind the actually observed *Punus padus* development, which is probably due to the unusually warm winter of 2013/2014

Comparison of *Padus racemosa* modelled and field observed development phases

- The color scale shows the probability of achieving the phase: if the color scale is 1 (red), then it is forecasted that in the corresponding area leaf unfolding has started
- On the x-axis - modelled or predicted observations of development phase
- On the y-axis - field observed development phase





Mathematical modelling performed at the University of Latvia revealed that **it is possible to calculate plant development using models**, and how improve these models

A study was done where strawberry flowering and harvest time was modelled for 3 periods in the Baltic States:

- **For past (1951-1980)**
- **For current time and close future (2001-2030)**
- **For far future (2070-2099)**

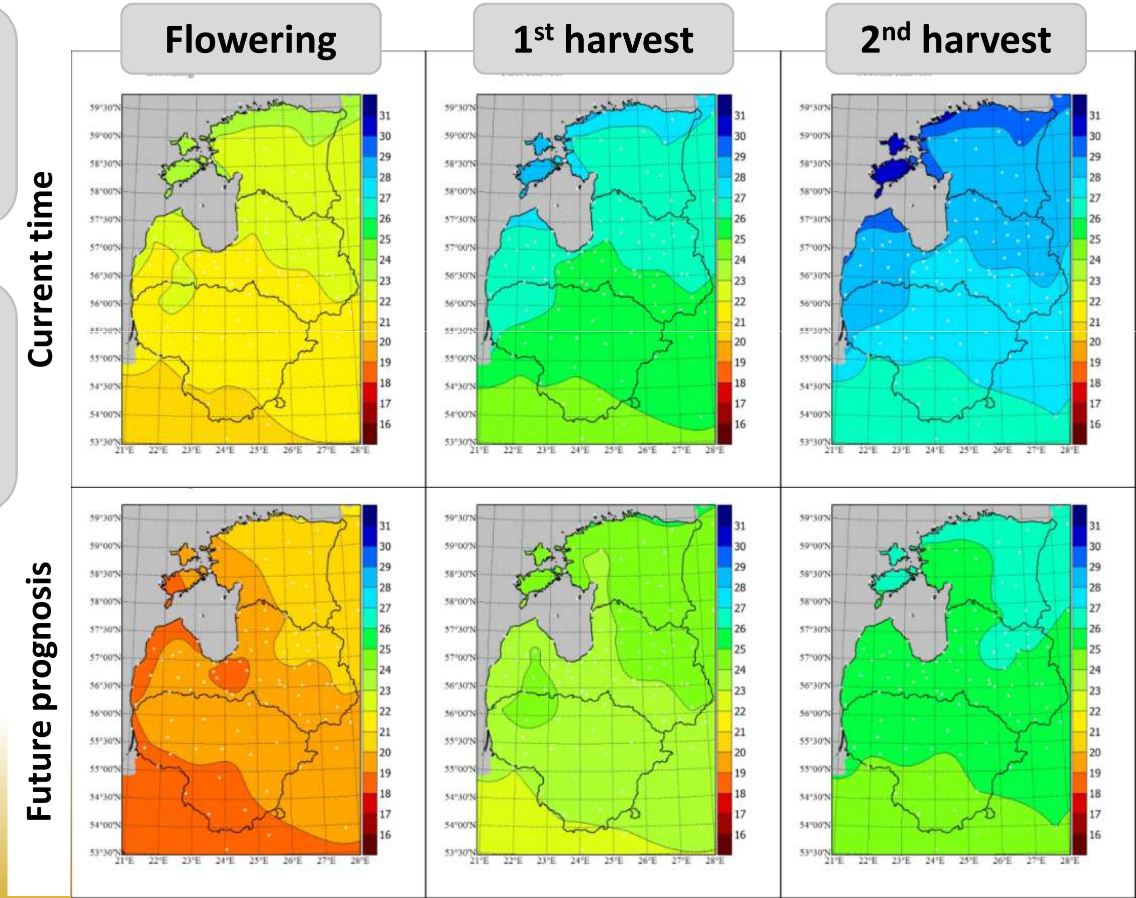
Nowadays strawberry flowering on average occurs from mid-May to June (20th-24th week of year) - earlier strawberry flowering occurs in southern Lithuania and gradually is moving to the north at a speed of 200-300 km/week

The study data showed that in 1951-1980 strawberry flowering occurred 1-2 weeks later in comparison with the period until 2030; while for the more distant future it is expected that flowering of strawberries will start already in late April (18th-22nd week of year)

Changes in forecasted and regional differences of strawberry flowering and ripening time

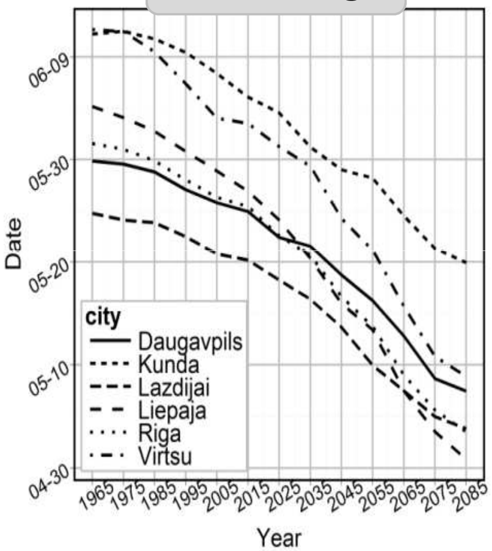
The first harvest could be two weeks earlier (22nd-26th week of year) in comparison with the current time when strawberries can be harvested in June-July (24th-29th week of year)

Modelled changes differ depending on the study site location relative to the terrain (in the heights later), and, in particular, in relation to the distance from the Baltic Sea and the Gulf of Riga

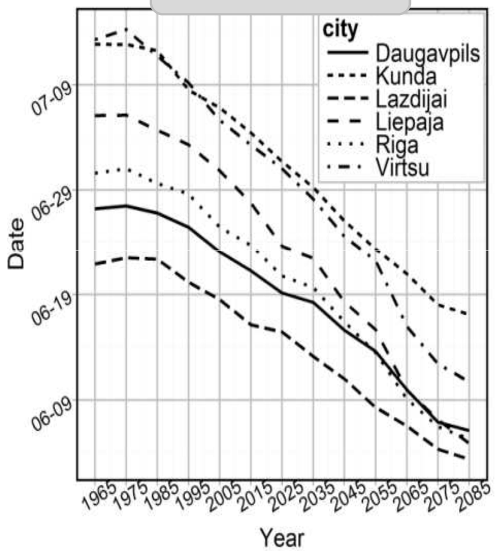


Regional changes of strawberry flowering and ripening time and future expectations (1965-2085)

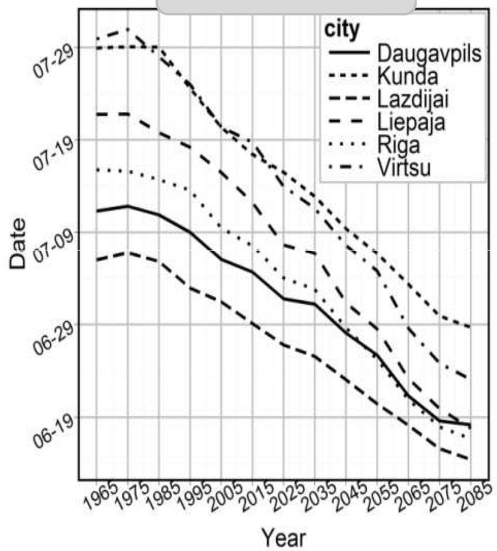
Flowering

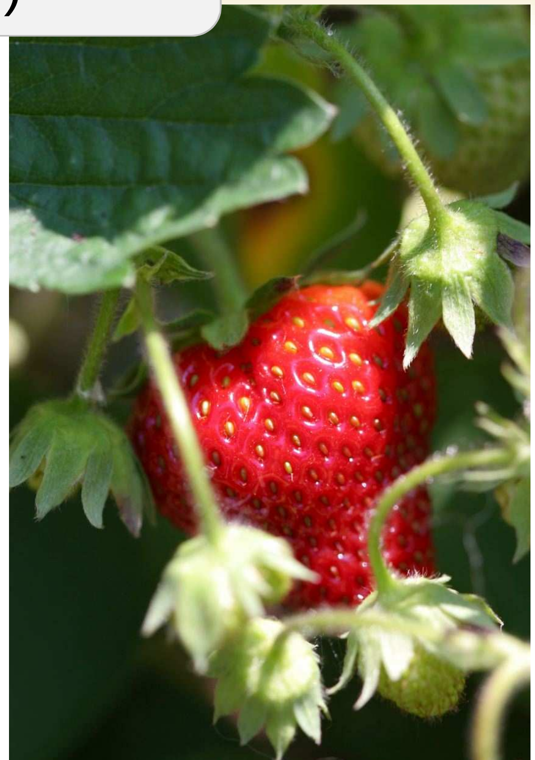


1st harvest



2nd harvest





It is forecasted that at coastal areas the changes will be greater than in the continental part, but these results should be interpreted with caution, as it should be noted that climate models could overestimate warming trends of the Baltic sea

IMPACT OF CLIMATE CHANGE ON FORESTRY

in the atmosphere will lead to a positive effect of forest growth - on average growth of trees will increase, furthermore, **in coniferous forests the changes will be greater than in deciduous forests**

Scientists have estimated that in northern Finland wood productivity could rise even by 70 %, but in areas with inadequate moisture forecasted increase of CO_2 level may induce additional risks for forest plantations

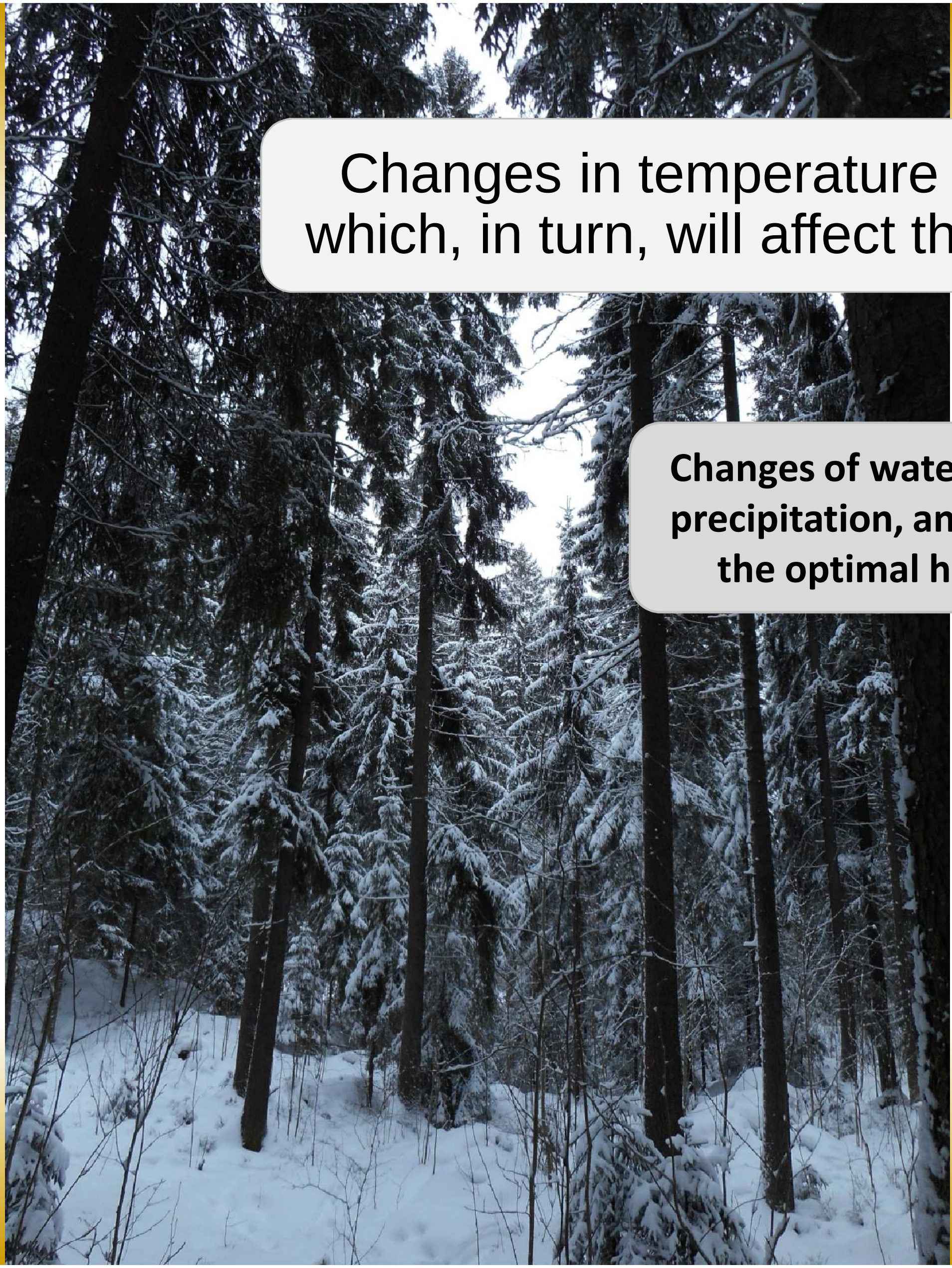
Also changes of air temperature can lead to both, positive and negative effects – warmth-loving species will increase their distribution area more to the north and mountain areas, while in the mountains many species will disappear being unable to adapt

Increase of air temperature will have a positive impact the growth of conifers (pine, fir) in northern Europe

Birch is the predominant tree species in the Baltic Sea region, the pilot studies revealed the positive changes – birch will grow better

In mixed tree forests temperature rise may rather promote tree growth risks and for some species, e.g., beech in this case growth will decrease

Studies already have shown that in northern part of Finland there a forest wood growth tendency is obvious, but for pine in southern Finland opposite – decrease, which is mainly affected by the water balance



Changes in temperature will lead to changes in snow cover which, in turn, will affect the seasonal water balance in forests

Changes of water balance will result in precipitation patterns and the amount of precipitation, and it may be one of the main forestry risks in the future, because the optimal humidity regime is very important for successful forest growth

Drought periods that in Latvian are forecasted to be longer and more persistent, for plants and trees can cause a growth stress

Drought negatively affects the plants' defense mechanisms and resistance to pests (insects) as well as against disease-causing microorganisms

Drought will increased the risk of nature fires, and it is foreseen that the number of forest fires will increase

It should be noted that during fires a lot of CO_2 is released into the atmosphere that leads to increased GHG levels in the atmosphere

Forecasted heat waves will also have an effect on forestry because, for example, heat waves in 2003 significantly reduced forest growth and productivity in part of Europe

Climate change impacts on forestry in the Baltic region – outlook summary of predicted impact scenarios

Impact of climate change	Country						
	Sweden	Finland	Estonia	Latvia	Lithuania	Russia	Germany
Forest areas	↑↑	↑↑	○	○	○	x	↑↑
Risk of forest fires	↑	↑	↑	↑	↑	↑	↑↑
Frost periods after bud forming time	↑	○	↑↑	↑↑	↑↑	↑↑	↓↓
Spruce bark beetle attacks	↑↑	↑↑	↑↑	↑↑	↑↑	↑↑	↑↑
Ecosystem net primary production of wood	↑↑	x	x	x	x	x	x
Ecosystem net primary production	↑↑	↑↑	↑	↑	↑	↑	↓

- ↑↑ – significant increase
- ↑ – small increase
- ↓↓ – significant decrease
- ↓ – small decrease
- ○ – no changes or tiny changes
- x – no data

In overall, it is expected that the impact of climate change on forestry in northern Europe will be mostly positive, however, for successful operation of forestry it is important to deal with appropriate forest management regarding adaptation that includes practice to grow climate-appropriate species, changes in thinning and felling time etc.

Effects of climate change in forests can be **a long-term** (species migration) and **a short-term** (pest invasion, forest fires, storms and strong winds), which in the future is expected to be more frequent and more intensive

Also short-term effects may pose a high risk and irreversible damage to the forest stands

Proper forest management will affect productivity much more than climate change

Thank you
for the attention!