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HYDROMETEOROLOGICAL INSTITUTE OF SLOVENIA

RAZPRAVE

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POSEBNA ŠTEVILKA

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SPATIAL INTERPOLATION OF PHENOLOGICAL DATA – FLOWERING OF LOCUST TREE *(Robinia pseudoacacia L.)* IN SLOVENIA

PROSTORSKA INTERPOLACIJA FENOLOŠKIH PODATKOV - CVETENJE ROBINIJE *(Robinia pseudoacacia L.)*

Klemen Bergant[1] and Lučka Kajfež-Bogataj[2]

POVZETEK

Nekatere rastlinske vrste (bioindikatorji) se močno odzivajo na klimatske razmere. Primer bioindikatorja je robinija (*Robinia pseudoacacia* L.), katere fenofaza cvetenja je močno korelirana s povprečno spomladansko temperaturo zraka. Prostorski vzorec začetka cvetenja robinije nam tako podaja informacijo o spomladanskih klimatskih razmerah na območju, ki ga obravnavamo. Vendar pa smo zaradi redke opazovalne mreže, primorani za prostorski prikaz fenoloških podatkov uporabiti različne prostorske interpolacijske tehnike za globalnejši vpogled v začetke posameznih fenofaz opazovane rastline. V našem primeru sta bili uporabljeni tehnika navadnega kriginga (ordinary kriging) ter kriginga z zunanjim vplivom (kriging with external drift) na podatkih o začetku cvetenja robinije za dve s klimatološkega vidika različni leti: 1978 (hladno pomlad) in 1994 (topla pomlad). V primeru uporabe prostorske interpolacijske metode navadni kriging ne uporabimo nikakršne informacije o reliefu, ki pa v veliki meri kroji lokalne klimatske razmere, ter s tem vpliva na odziv bioindikatorjev. Informativna vrednost kart izdelanih s pomočjo navadnega kriginga, ki pri interpolaciji uporablja le podatke, katerih prostorska porazdelitev nas zanima, je tako majhna. Izboljšamo pa jo lahko z vključitvijo informacije o reliefu v interpolacijsko metodo. Obstaja namreč dokaj močna korelacija med začetkom cvetenja robinije ter nadmorsko višino. Tako lahko podatke o nadmorski višini vključimo v interpolacijsko metodo kriging z zunanjim vplivom in jih upoštevamo pri ocenjevanju začetka cvetenja robinije na lokacijah, kjer opazovanja niso na voljo. Približno 30 opazovalnih postaj, kar je sedanje stanje glede opazovanj fenofaz robinije, ni veliko za izdelavo kart cvetenja robinije na tako zahtevnem reliefu, kot je to v Sloveniji. Zato k izboljšanju karte lahko v veliki meri pripomorejo dodatne spremenljivke (npr. nagib in orientacija terena), ki ima vpliv na pojav obravnavane fenofaze.

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Ključne besede: fenologija, navadni kriging, kriging z zunanjim vplivom, nadmorska višina

ABSTRACT

Some species (bio-indicators) react strong on climatic conditions. *Robinia pseudoacacia L.* is an example of bio-indicator, because it's flowering is highly correlated to spring air temperature. Spatial pattern of *Robinia pseudoacacia L.* flowering date can give us some information about the climatological conditions in spring on the area we are interested in. Because of limited number of phenological observation stations, we are forced to use different techniques for spatial interpolation of phenological data, to get more global view on beginning of different phenophases. The spatial interpolation methods ordinary kriging and kriging with external drift were used for interpolation of flowering date of *Robinia pseudoacacia L.* for, from climatological point of view, two different years: 1978 (cold spring) and 1994 (warm spring). In case of spatial interpolation method ordinary kriging, the information about relief, which strongly influence the local climatic conditions, is not included. The maps produced with ordinary kriging are not very realistic. For more realistic mapping, relief data were included as an additional information. The flowering date of *Robinia pseudoacacia L.* is spatially highly correlated with elevation. The elevation data can be used to improve the estimation of flowering date of *Robinia pseudoacacia L.*, on locations where the observations are not available. In this case the interpolation method kriging with external drift was used. About 30 phenological stations, where observations of *Robinia pseudoacacia L.* phenophases take place, which is present state, is not much for mapping the beginning of flowering especially on so agitated relief as it is in Slovenia. That is the reason why we need to use any additional available information (for example slope and aspect of terrain) to improve the quality of maps.

Key words: phenology, kriging, spatial interpolation

INTRODUCTION

A primary function of agrometeorological services is to provide data and information for the use of others. The latter include not only the public at large, but also research workers, business and other organizations. Portraying phenological data on maps is ideal method, if the aim is to draw particular attention to a spatial distribution. As in all environmental sciences also in phenology, the spatial distribution of data can help detecting the changes in environment.

Because of limited number of phenological observation stations, we are forced to use different techniques for spatial interpolating of phenological data to get more global view on beginning of different phenophases. This information is important for example in agronomy, medicine etc. Because some species (bio-indicators) react strong on different climatic conditions, phenological data are very important in climatology.

1 MATERIAL AND METHODS

An example for bio-indicator is locust tree (*Robinia pseudoacacia L.*). It's flowering is highly correlated with average spring temperature [Walkovszky, 1998]. Two techniques were used for spatial interpolation of phenological data - flowering date of locust tree: ordinary kriging and kriging with external drift.

Ordinary kriging is spatial interpolation technique, which is often associated with the acronym B.L.U.E for 'best linear unbiased estimator' [eg. Wackernagel, 1995 and Isaaks et al., 1989]. It is 'linear' because its estimates are weighted linear combination of the available data; it is 'unbiased' since it tries to have the mean residual or error equal to 0; it is best because it aims at minimizing the variances of the errors [Isaaks et al., 1989]. Only measurements of parameter we are interpolating is needed for spatial interpolation of data with ordinary kriging. On the other hand, by using kriging with external drift, we can include additional information in mapping procedure. In our case, the elevation data were used for more realistic mapping.

Spatial interpolation of flowering was done for two, from climatological point of view, different years: 1978 (cold year) and 1994 (warm year). Observation of locust tree phenophases, collecting the data, and quality control was done by Hidrometeorological institute of Slovenia.

2 RESULTS

The maps produced with ordinary kriging for both years are presented on Figure 1 and Figure 2.

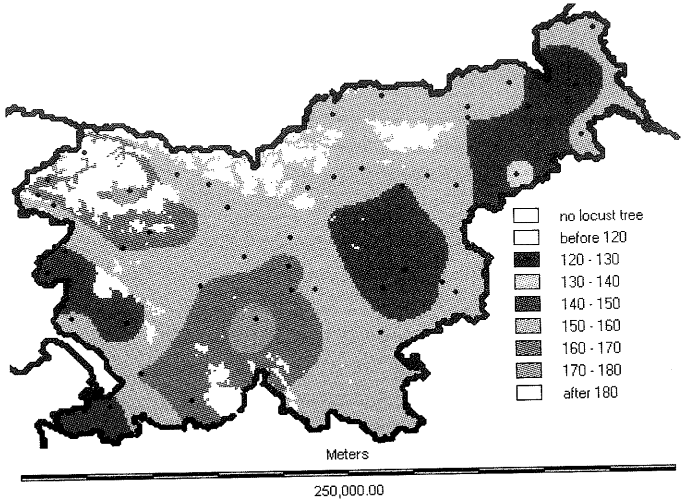

Figure 1: Flowering date (in Julian days) of locust tree (*Robinia pseudoacacia L.*) in year 1978 in Slovenia. Map was produced with ordinary kriging.

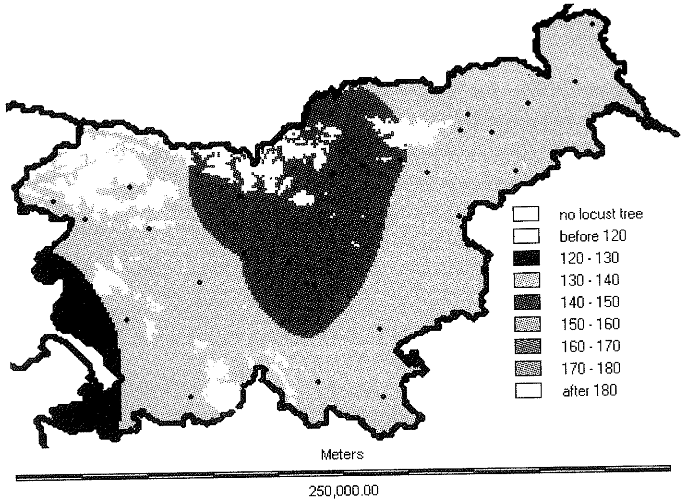

Figure 2: Flowering date (in Julian days) of locust tree (*Robinia pseudoacacia L.*) in year 1994 in Slovenia. Map was produced with ordinary kriging.

This maps are not very realistic, because they don't take into consideration the influence of different climatic conditions on different locations, which are mostly caused by agitated relief. Mapping of phenological events in mountainous areas presents many problems because the time of phenological occurrence usually changes very rapidly with small changes in elevation and because great influence of slope and aspect [Lieth, 1974]. With kriging with external drift we can use the information about relief in mapping the phenological data. In our case we used the information about elevation from digital relief model of Slovenia in 1 km grid. We would probably produce even better results when taking into account also the aspect and slope of terrain. Maps produced with kriging with external drift are presented on Figure 3 and Figure 4.

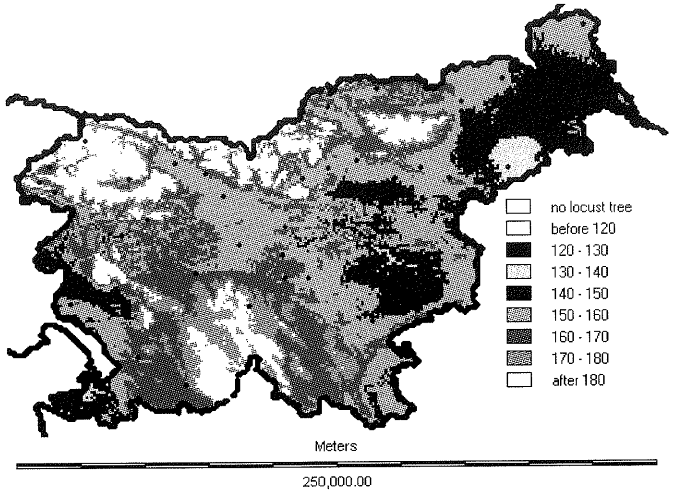

Figure 3: Flowering date (in Julian days) of locust tree (*Robinia pseudoacacia L.*) in year 1978 in Slovenia. Map was produced with kriging with external drift.

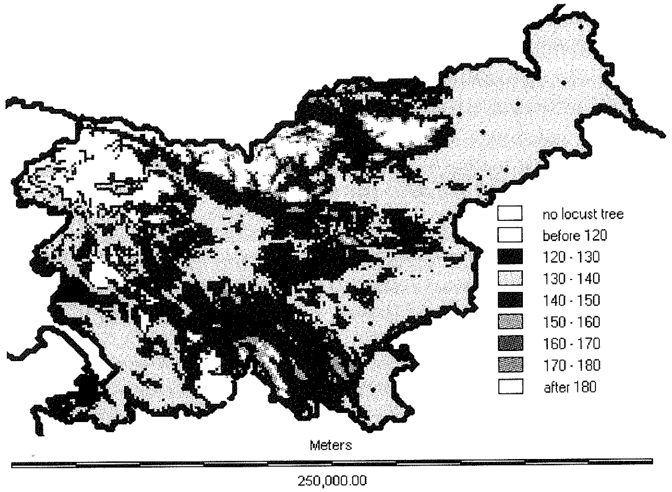

Figure 4: Flowering date (in Julian days) of locust tree (*Robinia pseudoacacia L.*) in year 1994 in Slovenia. Map was produced with kriging with external drift.

The correlation coefficient r^2 between flowering date and elevation was 0.69 ($r = 0.83$) for year 1978 which means strong correlation and 0.49 for year 1994 ($r = 0.70$) which means that almost half of variance can be explained with linear model using the elevation data. The critical values for r are with 99 % confidence level for 52 pairs (1978) 0.44 and for 31 pairs (1994) 0.55 [Zar, 1996]. Usually we are satisfied if half of variance can be explained with model.

On Figure 1, Figure 2, Figure 3 and Figure 4, we can see the difference between beginning of flowering in 1978 and in 1994. The flowering of locust tree started in average in 1994 about 20 days earlier than in 1978. The cause was in different temperature conditions in spring in those two years. In both cases we excluded the extrapolated data for locations higher than 1000 m above sea level, because the locust tree don't grow on such altitudes. Unfortunately, the number of observations of locust tree phenophases has decreased from 52 to 31 in period between 1978 and 1994 (Figure 1 and Figure 2).

3 CONCLUSIONS

About 30 observations of flowering date of locust tree, which is present state, is not much for mapping the beginning of flowering especially on so agitated relief as it is in Slovenia. We can use relief data for additional information in mapping of phenological data. This can be useful especially in mapping the long term averages of data. We can also use this technique for spatial interpolation of model results. Models are mostly based on observations of previous phenophases and measurements of temperatures. Using this information and relief data we can produce the prediction maps for different phenophases and different species which is of great importance especially in agriculture.

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SATELLITE SCANNED DATA IN THE FUNCTION OF VEGETATION MAPPING

SATELITSKO SKENIRANI PODATKI ZA KARTIRANJE VEGETACIJE

Marjan Jarnjak[1] and Ana Tretjak[2]

POVZETEK

Kartiranje vegetacije ima pri nas dolgo tradicijo. Za območje Slovenije obstajajo za zadnjih 250 let karte različnih meril in tematik, s katerih lahko razberemo položaj in obseg posameznih vegetacijskih tipov. Teh virov (vojaških in katastrskih kart) smo se poslužili pri rekonstrukciji razvoja in sprememb zemljiških kategorij in vegetacijskih tipov na Apaškem polju, poleg tega pa obravnavali tudi spremljajoče statistične podatke. Dobljene podatke smo nato primerjali s podatki kartiranj vegetacije zadnjih štiridesetih let ter z najnovejšimi statističnimi podatki.

Terensko kartiranje vegetacije je zahtevno, zamudno ter drago opravilo, kjer igra veliko vlogo usposobljenost raziskovalcev. Da pa bi zmanjšali vpliv subjektivne ocene ter zmanjšali čas in stroške pridobivanja podatkov, smo v ta proces vključili daljinsko zaznavanje. Uporabnost te metode za kartiranje vegetacije smo preizkusili na območju Apaškega polja in okolice, dobri rezultati pa predstavljajo osnovo za prihodnje raziskave.

Prikazana je tudi uporaba satelitsko skeniranih podatkov za kartiranje vegetacije in za izdelavo GIS-ov s poudarkom na skeniranih podatkih satelitov Landsat-TM in SPOT-PAN. Opisana je mono in multitemporalna analiza vegetacijskega pokrova Slovenije, pri časovni analizi pa je prikazan vpliv datuma skeniranja na skenirane vrednosti odbitega elektromagnetnega valovanja. Obravnavane so omejitve za možno operativno uporabo satelitsko skeniranih podatkov, kakor tudi uporaba obstoječih statističnih metod za statistično oceno kakovosti prostorsko razporejenih podatkov.

Ključne besede: daljinsko zaznavanje, groba klasifikacija, kartiranje vegetacije, mehka klasifikacija, Slovenija, zemljiške kategorije, satelitski podatki, pokrovnost tal, raba tal, GIS, časovna analiza, ocena kakovosti

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ABSTRACT

The vegetation mapping has had a long tradition in Slovenia. For this territory there are several types of cartographic material presenting the land use in various temporal and geographical scales. To reconstruct the development of changes in land use or in vegetation, we consider historical maps (old military and cadastral maps) and also statistic numerical data. Since 1962 the project Vegetation mapping of Slovenia has been carried out and now the whole area is mapped mostly in scale 1:50.000. From the beginning of vegetation mapping 36 years ago, there are already quite big changes in areal extension and in classes of vegetation.

In view to reduce the time and costs of re-mapping on classical way, the introduction of the new technology (satellite images, GIS) of vegetation mapping was initiated. That enables to take in consideration the whole large areas and to show the situation of vegetation in one moment. As an object of investigation the areas covered with forest in NE part of Slovenia were used, because this is, in view of the quality and quantity, the most stabile land use category. The results of that research should help to produce the procedure for elaboration of satellite images and thus help to vegetation mapping.

An overview of the use of satellite scanned data for vegetation mapping and for the compilation of various GISes is given with the emphasis on the data obtained by Landsat-TM and SPOT-PAN satellites. Mono and multitemporal analysis of the vegetation cover is described and the effect of acquisition date on scanned reflectance values demonstrated. Constrains for an operational use of the existing satellite scanned data are discussed as well as the use of existing statistical methods for quality assessment of the spatial distributed data.

Keywords: Hard classification, Land use, Remote sensing, Slovenia, Soft classification, Vegetation mapping, Satellite data, Land Cover/Use GIS, Multitemporal analysis, Quality control

In contribution some approaches to vegetation mapping, according to various techniques depending of specific type and origin of data, are presented. It's important to know the purpose and especially the expectations of investigation before we start with work, because of that depend the selecting and usage of input data and the methods of research. The best way for presentation is to show it on a specific example.

The aim of the one part of the project was to reconstruct the changes in land use over the last 230 years on the basis of old maps and statistical data. The next step was a comparison with the recent vegetation situation, derived from recent vegetation maps and with usage of satellite images and GIS operations.

The area of interest was Apaško Polje field (46°40' - 46°43' N; 15°47' - 16°00' E) which is situated in northeastern Slovenia in the transitional zone between the subalpine and subpannonian regions.

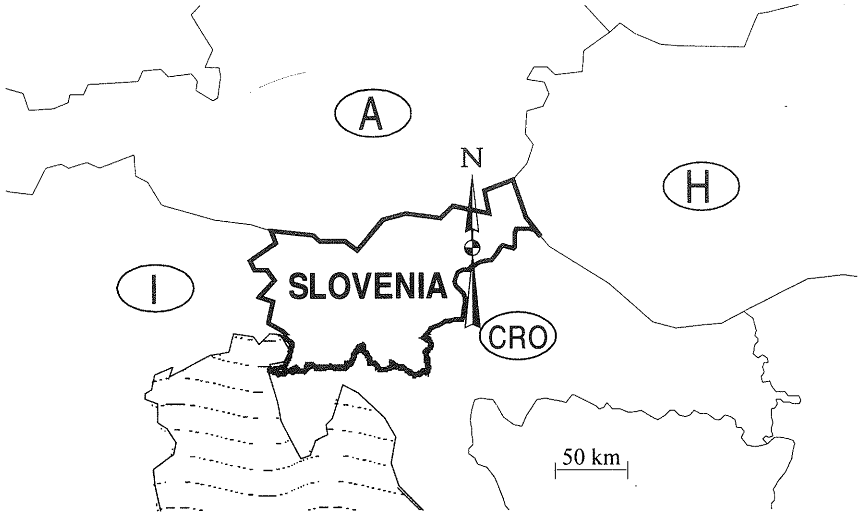

Figure 1: The position of Slovenia and Apaško polje field (arrow centre).

There are several types of cartographic material on Slovenia presenting land use in various temporal and geographical scales (Krušič 1996). The oldest map is a military map from the mid 18th century. It is very superficial and can hardly be used for the purpose of vegetation analysis. Later, with the introduction of taxes in the early 19th century, more sophisticated cadastral maps were prepared. To chart the changes in vegetation over the last 230 years, military maps from the 18th century, cadastral maps from the 19th century, numerical data from 1900, and current cadastral statistical data were used.

The military maps were made between 1763 and 1787 exclusively for military purposes and were part of the Emperor Joseph II Land Survey (Rajšp et al. 1996). In that period, most of present-day Slovenia belonged to the Austrian Empire. The maps were drawn to a scale of approximately 1:28.800, and distances were measured in hours and footsteps (Rajšp et al. 1996). They are not sufficiently accurate to be processed by the GIS. Nevertheless, they are useful because in addition to other objects of military importance, fields, pastures, and forests were mapped. The positions and areas of the land use categories were considered and transferred to our topographic maps by interpolation.

The next step was to study and process the cadastral maps made between 1819 and 1823 for the Economic Cadastral Survey for Regulation of Land Taxes ordered by Austrian Emperor Franz I. The maps were made primarily for taxation purposes and were very precise in positions, measurements, and descriptions of the land use categories. To transpose the maps, a mathematical and graphical trigonometric net was used to redraw every cadastral unit on a separate sheet on a scale of 1:2.880 in Cassini cartographic projection (Triglav 1996). The transfer of the positions and areas of the land use categories was also made by interpolation because the originals, which are kept in the Archive of the Republic of Slovenia, are in bad condition.

Data on areas of different types of land use from 1900 (Anon. 1904) obtained from the inventory of cadastral measures from 1824 and 1864 and numerical data on current land use are also included.

After the consideration of historical data about vegetation on Apaško polje field the conclusion was that the areas of specific categories haven't change for more than a few percent in comparison with nowadays situation.

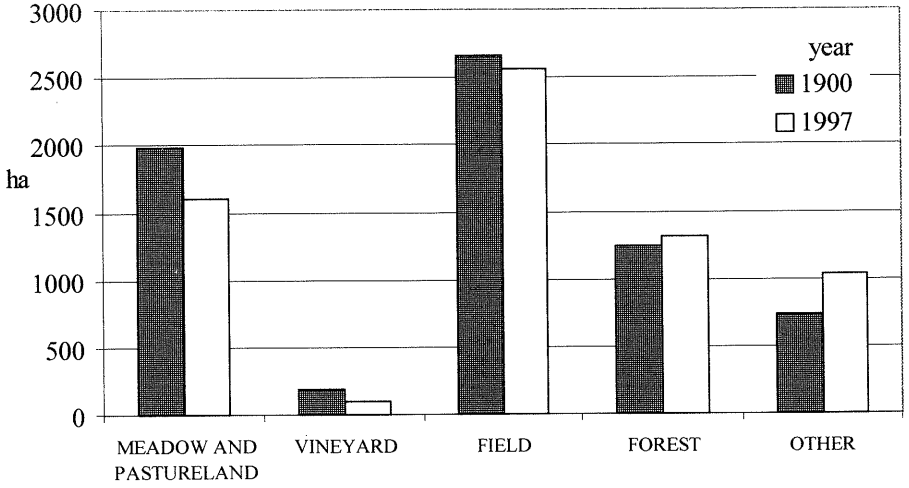

Figure 2: Land use categories according to historical maps and statistical data.

The vegetation mapping has a long tradition in Slovenia. However in our institution we haven't work with chronological or periodical observations of vegetation, but mostly with situation at present moment. There is no permanent stations or points where this researches would be made. In past 36 years the project Vegetation mapping of Slovenia has been carried out and now the whole area is mapped mostly in scale 1:50.000. Yet, most of the maps remain in manuscript form.

There is a few possibilities to perform field mapping and can be declared as so called classical approach. Field mapping depend on type of vegetation and map scales. They also demand previous room preparation (consideration of aero photographs, topographic maps, already existing vegetation maps, intersectal diagrams). For field observations there is a need for well trained observers with a lot of experience. In many places, the situation of vegetation can be changed in both ways, quantitatively and qualitatively. For recognition of those changes, we could start to remap all parts of country, but in the end of that process, while this procedure of mapping on classical way is so long terming, we could start again.

The results depend on personal judgement, and therefore the possibility of mistake always exist. To avoid or reduce the possibility of subjective estimation, and to reduce the time and costs of field inspections, we introduced teledetection (in co-operation with Spatial Information Centre from Centre of Scientific Research of the Slovenian Academics of Sciences and Arts) in our researches. That enables to take in consideration the whole large areas and to show the situation of vegetation in one moment.

The main idea was to examine the applicability of remote sensed data for our needs.

The research began with unsupervised image classification, since we wanted to show the capabilities of Landsat TM data and remote sensing in vegetation studies (Landsat TM, channels 3, 5, 7 infra red spectre, with 30x30m resolution). After unsupervised classification the objects were divided into 6, 10 and 14 categories. The results were compared with vegetation maps, aero photographs and field observations to divide forests as an object of investigation from other categories.

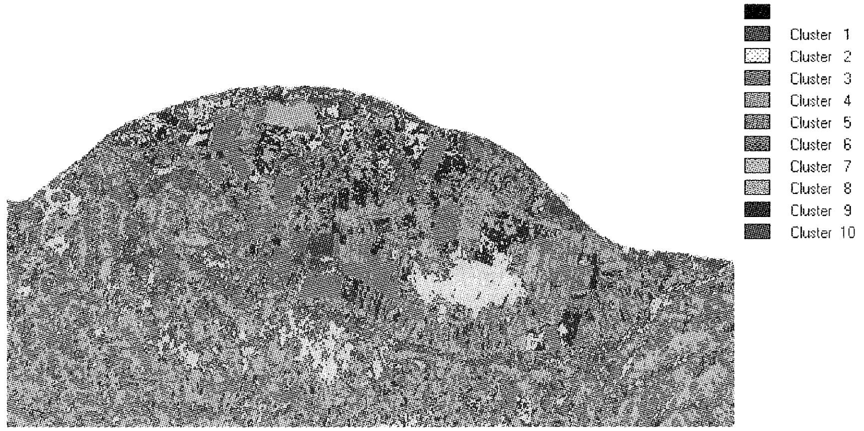

Figure 3: Field objects after unsupervised classification divided into 10 categories.

After some preliminary results, supervised classification was used. The image was georeferenced, preprocessed, and classified using Erdas Imagine (Erdas, Inc.). In the final step, the results were transferred into ArcInfo and ArcView databases (ESRI, Inc., Redlands, California, USA) to produce maps and compare them with other data. The remote sensing produced a map that correlates quite well with the map produced by field mapping. We also found the changes in category of forest in the SE of area observed. After another field inspection we found, that previous *Castaneo-Fagetum* forest was cut and the *Quercus robur* dominated forest is located on the lower part of the slope and there is also an ash plantation on the slope.

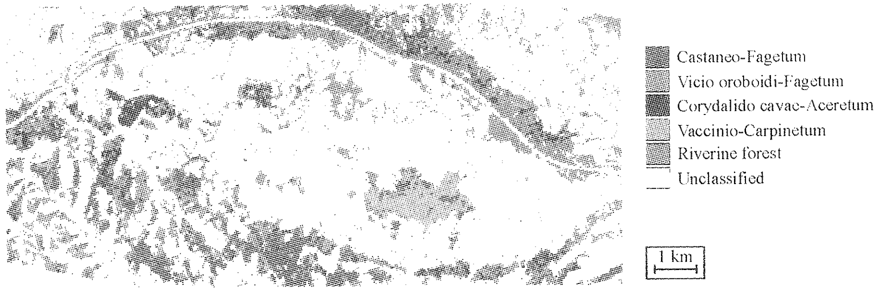

Figure 4: Forest types according to the supervised classification of the remotely sensed image based on several field inspections.

The usage of teledetection in vegetation mapping proved to be very useful. Our next task is to develop the "key", with other words to determine the process of getting information about the vegetation types in geographically similar areas, which are larger, distant, or difficult for field observation, on the base of results derived from a genuine test areas. We suppose to be able to predict and determine the vegetation with high accuracy from combination of remote "key" and digital model of relief, digital pedological data, radar images and advanced classification techniques.

1 COMPILATION OF THE LAND COVER GIS OF SLOVENIA - 1993 FROM SATELLITE SCANED DATA

For the needs of agricultural statistics, national agricultural policy, land use planning and monitoring environmental changes a uniformly produced digital land-cover map of Slovenia has been compiled on the Department of Statistical Geomatics and GIS of the Statistical Office of RS in 1995 from Landsat-TM/93 satellite scanned data by stratification process with the minimal mapping unit of 20 hectares. This first choropleth digital land cover map of Slovenia confirmed the long suspected but never estimated high increase of the areas under forest and built-up areas on the account of agricultural land.

In 1996 it was decided to improve the content of the existing land cover map of Slovenia by the compilation of a Statistical Land Cover/Use GIS of Slovenia on the Regional level for state 1993. First, the nomenclature was elaborated. No satisfactory nomenclature that would clearly separate land cover categories from land use classes using only Landsat-TM data has been defined, since the Landsat-TM satellite scanned data give information only on reflected values of the land cover and no information on whatever use of the feature whose reflectance value is captured within the 30 m x 30 m pixel(s): wooded land cover, agriculture land use, water land cover, bare rocks as land cover, built-up as land cover (within that land use of areas under houses with yards, areas under roads and under railways with railway stations, areas of recreation under vegetation and masks of larger built up places) and category other, comprising land dumping grounds, gravel pits, quarries, etc. The descriptions of defined land cover categories and land use classes are published in: Rapid Reports No. 42/98.

As the base map the georeferenced mosaic of Slovenia, compiled from a set of Landsat-TM/93 data was used. These data were the only reliable source of the state of land cover in 1993 uniformly covering the whole area of Slovenia. The georeferenced mosaic with the RMS < 30 m was produced on the Statistical Office of RS. In addition official georeferenced databases that would help to determine the land cover categories and land use classes as: digitised boundaries of forest, draft version of digitised boundaries of water, centroids of houses, vectors of roads and railways and data from the register of digital administrative boundaries were used. A more detailed description of these data as well as the results of the compiled GIS are given in Rapid Reports no 42/98.

2 UPDATING THE LAND COVER GIS OF SLOVENIA TO STATE 1997

The first objective of the follow up project is to update the existing Land Cover GIS of Slovenia from the state in 1993 to the state in 1997. In addition to the updated georeferenced databases used in the compilation of the Land Cover GIS of Slovenia-state'93 the following sets of raster data are used:
- set of Landsat-TM/97 data;
- orthorectified Spot-Pan/96-97 data, given to our disposal from the Ministry of Defence;
- vector data of locations of dumping grounds, gravel pits and quarries.

Areas covering the Spot-Pan/96-97 rectified images are being cut from Landsat-TM/97 and Landsat-TM/93 mosaic, resampled to pixel size of 10 m and georeferenced to the Spot-Pan/96-97 scenes with RMS < 10 m. The first two visible bands of Landsat-TM/97 were replaced by Spot-Pan/96-97 band.

To obtain a better discrimination between bare dry soil and built-up areas two filters were applied over Spot-Pan/96-97 data:
- the summary 5x5 filter that increases the contrast along object edges and results in a multimodal distribution of reflectance values with an increased standard deviation;
- the 3x3 edge filter applied over original Spot-Pan/96-97 data to discriminate high reflectance built-up areas from all other features.

The resulting image produced from these three bands, resembles a pseudo-colour composite and enables a significant better visual discrimination between built-up areas and bare dry soil, undiminished discrimination of other categories and an improves the discrimination of grassland and clear-cuts within forest areas.

3 ESTIMATION OF LAND COVER CHANGES

The second goal is to estimate the land cover changes in the period 1993:1997. The two sets of Landsat-TM data with acquisition dates early summer 1993 and spring 1997 are in the process to be analysed.

The image to image georeferencing is performed. In order to avoid misregistration TM/97 scenes are referenced to the georeferenced TM/93 mosaic with RMS less than 1/2 pixel accuracy.

In order to target possible locations of land cover change in the time span 1993:97 TM bands 6, 7 and 2 from both years are being classified separately. In spite of the fact that the TM band 6 has a more coarse pixel of 120m x 120m it is expected to be useful since areas having hotter sun-facing slopes will be more outstanding and the valley regions in hilly and mountainous areas better determined. The boundary between the forested areas and the areas being under shadow is expected to be better visible in the early spring date of 97-TM data compared to the summer date of TM-93 data. Thus, the difference between the shadows in the valleys that would be predominately classified into forested areas will be reduced to a minimum. Areas that have not been under vegetation on both scanning dates will have on both images brighter values in band 6 due to the absorbed solar radiation thus emitting thermal energy.

For a more detailed classification, TM bands 4, 5 and 7 are being used. As the scenes from both years are haze free, TM bands 3 will be included. It is assumed that the use of these bands will offer the highest within vegetation separability and will be therefore used for the classification *(Fig.5)*. The separate classification of scenes instead of the mosaic as a whole will eliminate the difference in scanning dates of the scenes and though contribute to a better interpretability of obtained clusters.

The updating has been till now finished over one statistical region where in addition quality assessment of the obtained results has been performed using the error matrix method on two segments, each of size 900 hectares. The overall accuracy of the compiled GIS-'97 is higher than 90%, the agriculture land use is estimated with an accuracy higher than 90% and the wooded land cover with an accuracy between 73% - 94 %.

It was expected that the most dynamic land cover changes did take place in the built-up category. We did not expect to be able to classify individual houses with these satellite data. Since it was our attempt not only to identify the extend of the change in the built-up category but also to estimate how much of the built-up area did expand in the analysed time on the account of other land cover categories buffered centroids from year 1993 were subtracted from buffered centroids from year 1997. The average rate of new built-up hectares per year was calculated. The identification of the underlying land cover category showed that 855 hectares of agriculture land changed to built-up land cover and only 41 hectares of forest has changed to built-up land cover. The distribution of augmented built-up areas within each statistical region over various land cover categories is reported in Rapid Reports No 121.

Figure 5: Example of detected land cover change in the period from 1993 to 1997 over an area in updated Land Cover GIS of Slovenia (Gauss-Krüger co-ordinates of the UL corner: X/Y= 5606000/5162000) where **gray colour (arrow pointed) indicates the extent of the changed wooded land cover to agriculture land use.**

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SPATIALISATION OF GRAPEVINE PHENOLOGICAL DATA AT DIFFERENT SCALES BY USING AN ARTIFICIAL NEURAL NETWORK

PROSTORSKI PRIKAZ FENOLOŠKIH PODATKOV ZA VINSKO TRTO V RAZLIČNIH SKALAH Z UPORABO NEVRONSKIH MREŽ

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POVZETEK

Znanje o fenologiji poljščin igra pomembno vlogo na različnih področjih človekovih aktivnosti (v kmetijstvu, alergologiji, agrometeorologiji...). Pri tem pa je pomembna tako časovna, kot prostorska variabilnost fenoloških podatkov. Pri časovnem spremljanju fenološkega razvoja rastlin gre za opazovanja različnih fenofaz na fenoloških postajah. V primeru, da pa nas zanima prostorska variabilnost fenoloških podatkov, pa potrebujemo mreže fenoloških opazovalnih postaj, ki pa jih je težko načrtovati in organizirati. Zato so nam lahko v veliko pomoč različne prostorske interpolacijske tehnike (kot na primer kriging, nevronske mreže, ...). Z njimi na podlagi omejenega števila podatkov iz fenoloških postaj, ki so razporejene na nekem območju, ocenimo vrednosti za celotno obravnavano območje. S tem dobimo bolj globalen pogled na prostorske vzorce razporeditve posameznih fenofaz. V našem primeru smo za oceno uporabnosti metode z nevronskimi mrežami uporabili opazovane in modelirane fenološke podatke za vinsko trto (*Vitis vinifera* L.) na dveh prostorsko kompleksnih ter različnih območjih - farma "Fattoria di Poggio Casciano", Firence - Italija (velikost približno 1 km^2) ter Toskanska regija - Italija (velikost približno 20.000 km^2). Poleg fenoloških podatkov so bili uporabljeni tudi klimatološki in geografski podatki. V primeru Toskanske regije je bil uporabljen digitalni relief z ločljivostjo 1,1 km, v primeru farme "Fattoria di Poggio Casciano" pa digitalizirani kartografski podatki z ločljivostjo 5 m. Od klimatoloških podatkov so bile za področje Toskane uporabljene dnevne vrednosti sledečih parametrov za 67 meteoroloških postaj: minimalna, maksimalna in povprečna temperatura zraka ter dnevna količina padavin in globalno obsevanje. V primeru fenoloških podatkov, je bil za simulacijo fenoloških faz vinske trte v regionalni skali (Toskanska regija) uporabljen fenološki model, v lokalni skali (farma "Fattoria di Poggio Casciano") pa podatki iz opazovanj. Rezultati kažejo, da nam modeli z nevronskimi mrežami lahko dajo dobre ocene fenološkega razvoja tako na lokalni, kot na regionalni skali, ter tako bolj globalen pogled na prostorsko porazdelitev fenoloških podatkov na določenem območju. V regionalni skali je korelacija med simuliranimi podatki ter podatki ocenjenimi z modelom, ki uporablja nevronske mreže, izredno visoka (r=0,89 do 0,96 pri 1% tveganju), v lokalni skali pa nekoliko manj (r=0,55 do 0,75). V splošnem lahko trdimo, da metoda, ki temelji na principu nevronskih mrež, predstavlja možnost za ocenjevanje prostorskih vzorcev v različnih prostorskih skalah. Seveda je možna razširitev metode tudi na druge kulturne rastline.

Ključne besede: fenologija, Italija, prostorska porazdelitev, regionalna skala

ABSTRACT

The knowledge of crop phenology is a very important step in many fields of human activity, such as agriculture, allergology, agrometeorology. To make a complete characterisation of phenophase trends, both the time and the spatial distribution of crop phenology are necessary. Unfortunately, while the time of phenological stages can be followed by means of local monitoring network, the spatial distribution requires an extension over the land surface of phenological measurements network that is extremely difficult to plan and organise. Thus interpolation techniques (such as kriging, fuzzy, neural network, etc.) can represent useful tools to extend over the land surface site phenological data. With this aim, observed and simulated phenological data of grapevine were used to evaluate the performances of neural network approach for extending site data at different spatial scales (farm and region). Finally the main problems and perspectives were discussed.

Key words: Vitis vinifera, spatial interpolation, macro and microscale

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1 INTRODUCTION

The knowledge of the temporal trend of the phenological phases (beginning, full, and conclusion) represents one of the basic topics helping human activity in many fields. For example, in agrometeorology, phenology allows to quantify the relationships between plants and environment, in allergology it allows to assess pollination production and thus to advise about the risks due to allergenic plants; while in agricultural activity, phenophase trends can strongly affect the efficiency of cultivation techniques, and thus their monitoring is one of the basis for improving farmer decision making.

Network of phenological measurements provides a continuos monitoring of crop development. Phenological scales and field technicians are generally the basis for a permanent and continuos evaluation and control of phenological conditions. These measurements must be carried out during the growing season and evaluated according to the meteorological conditions and the different characteristics of territory. Extension services are generally the most suitable organisation for this activity. Collected data are stored and elaborated and then they are diffused among the users by means of different communication techniques (such as phone, fax, radio, bulletin, post, Internet, etc.)

Two main consideration, however, must be pointed out: the variability of phenological trend over the land surface and the cost of monitoring management. As regards the first point, the phenological development of crops shows a high variability also at small spatial scale. This is generally due to many factors, such as macro-geographic (mountain, lake, sea, etc.) and micro-topographic (elevation, slope, distance from valley bottom, aspect, etc.) elements. In particular, in hilly areas, these elements vary consistently at very small scale thus causing strongly differences in the development of crop. These considerations confirm the need of a very localised monitoring of phenology, that however, it is limited by the high cost of monitoring management (staff of field technicians, elaboration and distribution of collected data, etc.).

To solve these problems, spatialisation techniques can represent a suitable alternative. Starting form a limited number of phenological observations, these techniques allow for an extension of phenological data to get a more global view of the distribution of phenophases in the studied area. In such a way, the effect of the territory can be evaluated and monitored with a limited employment of staff, and spatial pattern of phenophases can be distributed almost in real time.

Many are the approaches proposed for the spatialisation of data. Their suitability depends on the available data (weather, productivity, phenology, etc.) and the characteristics of the expected outputs. Recent works have demonstrated that data taken by the Advanced Very High Resolution Radiometer (AVHRR) mounted onboard of the National Oceanic and Atmospheric Administration (NOAA) satellites are useful for eco-climatic classification (Maselli et al., 1996). Other useful means that can be used to explore the spatial distribution, are represented by semi-variance analysis and kriging, which are fundamental instruments of Geostatistics (Davis, 1973).

Artificial neural networks, which are capable of learning relationships in pattern of information, seems to be a very useful tool for the spatialisation of data. A neural network can be viewed as a computer system that is made up of several simple and highly interconnected processing elements similar to the neuron structure found in the human brain (McClelland et al., 1986 a, b). Problems which are normally not solvable by traditional algorithmic approaches can be solved with a neural network approach (Davidson and Lee, 1991). Neural network are suitable for problems which require the interpretation of large data sets. In addition they can also be used to solve problems in which the inputs and corresponding output values are known, but the relationship between inputs and outputs are not well understood. These conditions are commonly found in many environmental and agricultural applications. Specifically neural network models have successfully been used in biological applications to predict processes such as crop phenology (e.g. soybean), insect pest treatments threshold, weather forecast, optimum temperature in greenhouses, etc. (Crisci et al., 1998).

On the basis of these considerations the performances of neural network models to extend phenological observation of grapevine (Vitis vinifera L.) over land surface were evaluated. Specifically, two spatially complex areas with a different extension (1 Km^2 and 20,000 Km^2) located in Central Italy were selected, and the results were analysed considering the reliability of the up-scaling methodology and discussing the possibility of an operational application of this approach.

2 MATERIAL AND METHODS

2.1 STUDIED AREAS

Neural network were applied in two areas, with a different spatial scale. The first was an area of about 100 ha locates in the “Fattoria di Poggio Casciano” farm, Florence-Italy (11°20’ Long. East and 43°42’ Lat. North) in which the morphological characteristics are extremely complex (three main valleys East-West oriented, altitude between 150 to 260 m, slopes exposed towards South and North with an average slope of 12-13 %). The second area was the whole territory of Tuscany Region, Central Italy (20,000 Km^2), which is characterised, as well as the previous one, by a very complex morphology (the Appenine mountains on the North-East, several river valleys East-West oriented (Arno, Ombrone, Serchio rivers) and the sea on the West border).

2.2 DIGITAL ELEVATION MODEL

Morphological and geographic data were collected for both areas. Specifically, a digital elevation model (DEM) of the Tuscany Region with a pixel size of 1.1x1.1 Km was generated by digitising and processing the contour lines every 100 m taken from 1:100000 geographic maps of the Istituto Geografico Militare Italiano (IGMI). Two digital images with North-South gradient and distance from the Tyrrhenian Sea were also produced by apposite Fortran programs. A DEM of Fattoria di Poggio Casciano farm was obtained by digitising and processing the contour lines every 5 m taken from 1:5000 Carta Tecnica Regionale of the Tuscany Region.

2.3 CLIMATIC DATA

A dataset of climatic data (1961-1990) of Tuscany was constructed. In particular, observed daily climatic data were collected for 67 stations evenly distributed over the region. The dataset consisted of five variables: minimum, maximum and mean air temperature, total precipitation and global radiation. All the data were error checked and transferred to a PC in a consistent format.

2.4 PHENOLOGY DATA

Data on grapevine phenology for the evaluation of the performances of the up-scaling methodology were obtained from different sources. A calibrated and validated model was used to simulate grapevine phenology at regional level. In the model crop ontogeny is divided in two periods: a development period between bud break and bloom and a fruit growth period between bloom and maturity. Duration of the period between bud break and bloom was calculated by setting the number of leaves on a shoot equal to 17 at bloom as a function of the rate of appearance of leaves[4]. The duration of the period between bloom and maturity was calculated as a function of cumulative degree days. This period is divided into two sub-phases which are the period between bloom and the veraison and the period between veraison and maturity.
At local scale (Fattoria di Poggio Casciano farm), monitoring of crop development was made on cv. Sangiovese (the most representative cultivar of that area). In 13 different locations during 1997 and 1998, phenophases of grapevine (budbreak, bloom, onset of fruit growth, veraison and maturity) were monitored with weekly intervals on a sample of about 10 vines. To define and describe the phenological stages, the scale proposed by Eichorn and Lorenz was used.

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[4] The rate of leaf appearance is calculated on the basis of the mean daily temperature assuming that the rate of leaf appearance declines during ontogeny with constant temperature (Miglietta et al. 1992)

2.5 NEURAL NETWORK UP-SCALING METHOD

In this study a neural network model was used for extending phenological observations over the land surface. In particular, means and coefficient of variations of model outputs computed for 31 years at ground stations were used to train and validate the neural network models at regional level. The input variables considered for the development of neural network models were longitude, latitude, altitude and distance from the sea corresponding to the ground stations. At the farm level, data observed over two years of experiment were used to develop neural network models. The input variables were mainly micro-topographic parameters, such as altitude, slope, aspect and difference in level from the valley bottom. Each of the above mentioned inputs of the neural network models were connected to a set of hidden nodes, and each of the hidden nodes was connected to all the output nodes, using three-layer feedforward neural networks.

3 METHODOLOGY PERFORMANCE

The performance of this methodology were tested dividing the study stations in two groups: the first for training (40 stations for Tuscany and 8 stations for the farm) and the second for testing (27 stations for Tuscany and 6 stations for the farm); and then comparing the estimated parameters obtained using the interpolation methodology with the observed phenological data by means of conventional statistics (correlation coefficient, MBE and RMSE).

4 RESULTS AND DISCUSSION

The application of neural network models provided a good estimation of phenological development both at regional or local scale. In the first case (table 1) the higher variability of phenological stages for the study area determined relative large deviance between estimated and simulated data (MBE = 3 to 10 days; RMSE = 8 to 30 days). However, the correlation coefficients (r= 0.89 to 0.96) obtained were statistically significant for all the phenological phases (P<0.01). Whilst, the application at local scale (table 2) showed lower deviances (MBE = -2 to 1.5 days; RMSE = 2.5 to 7 days), but at the same time, also the correlation coefficients were lower (r=0.55 to 0.75). Moreover, at regional scale a higher accuracy was achieved in the up-scaling of budbreak, bloom and veraison stages (table 1); while, at local scale higher accuracy was obtained for bloom, onset of fruit growth and veraison stages (table 2). In both studies however, the lowest accuracy was obtained for maturity stage (tables 1 and 2).

Table 1: Statistical analysis of the neural network predictions for a Three-Layer Feedforward NN with 40 Training and 27 Validation Scenarios. * Significant st $P<0.05$; ** Significant at $P<0.01$.

	Training			Validation		
	MBE	RMSE	r	MBE	RMSE	r
Budbreak	0.24	9.15	0.93**	3.14	8.79	0.96**
Bloom	0.15	6.77	0.95**	2.68	6.60	0.97**
Veraison	0.10	14.99	0.96**	2.39	10.82	0.99**
Maturity	0.61	27.71	0.88**	11.47	30.87	0.89**

Table 2: Statistical analysis of the neural network predictions for a Three-Layer Feedforward NN with 18 Training and 12 Validation Scenarios. * Significant at $P<0.05$; ** Significant at $P<0.01$.

	Training			Validation		
	MBE	RMSE	r	MBE	RMSE	R
Budbreak	0.01	4.96	0.71**	-0.86	4.04	0.55*
Bloom	-0.02	2.17	0.91**	1.57	3.91	0.64**
Onset of fruit growth	0.03	3.43	0.73**	0.66	4.09	0.61**
Veraison	0.02	1.17	0.95**	0.06	2.55	0.76**
Maturity	-0.10	6.74	0.60*	-2.11	6.80	0.54*

The spatial patterns of the phenological phases for both areas were reported in figures 1 and 2. As regards the regional pattern, the phenological development of grapevine was predicted to be faster in the areas located along coast and in the central areas, included the zones between Florence and Siena where the highest quality wine is produced. Whilst, most northern and eastern areas are unsuitable for grapevine cultivation due to the adverse climatic conditions (Figure 1).

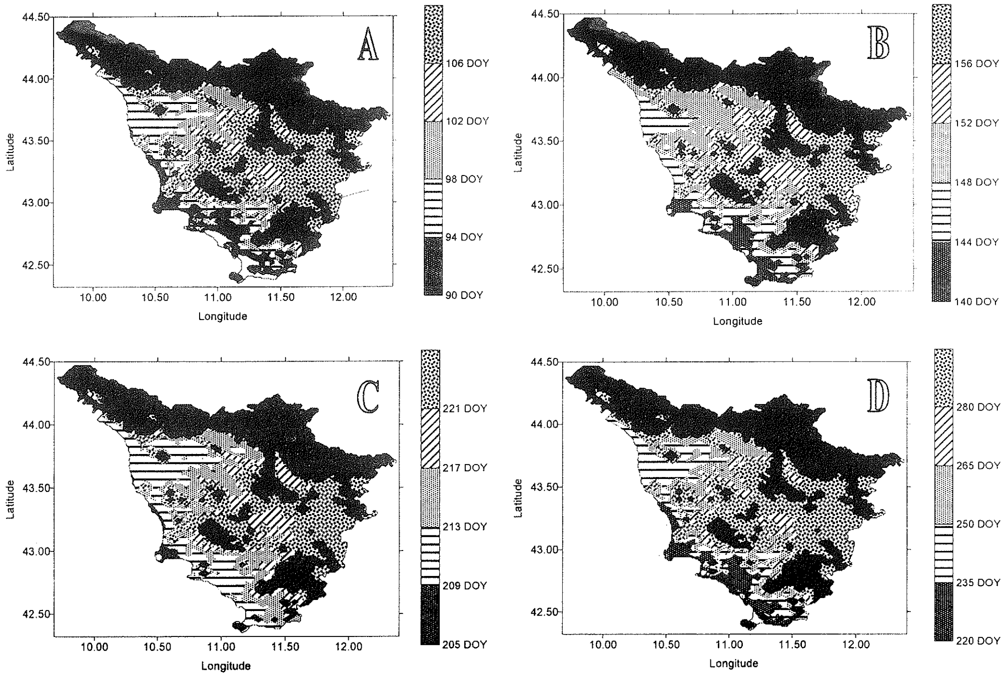

Figure 1: Neural Network prediction of means of budbreak (A), bloom (B), veraison (C) and maturity (D) dates for grapevine for Tuscany Region. Unsuitable areas are coloured in black.

At local scale the spatial pattern of the phenological development of cultivar Sangiovese showed that the growing season (budbreak dates) starts earlier in the fields South-West oriented, while Northern aspects and valleys seemed to show later budbreak dates. This spatial distribution pattern remained quite constant during all the season, independently from the considered phenophase (figure 2).

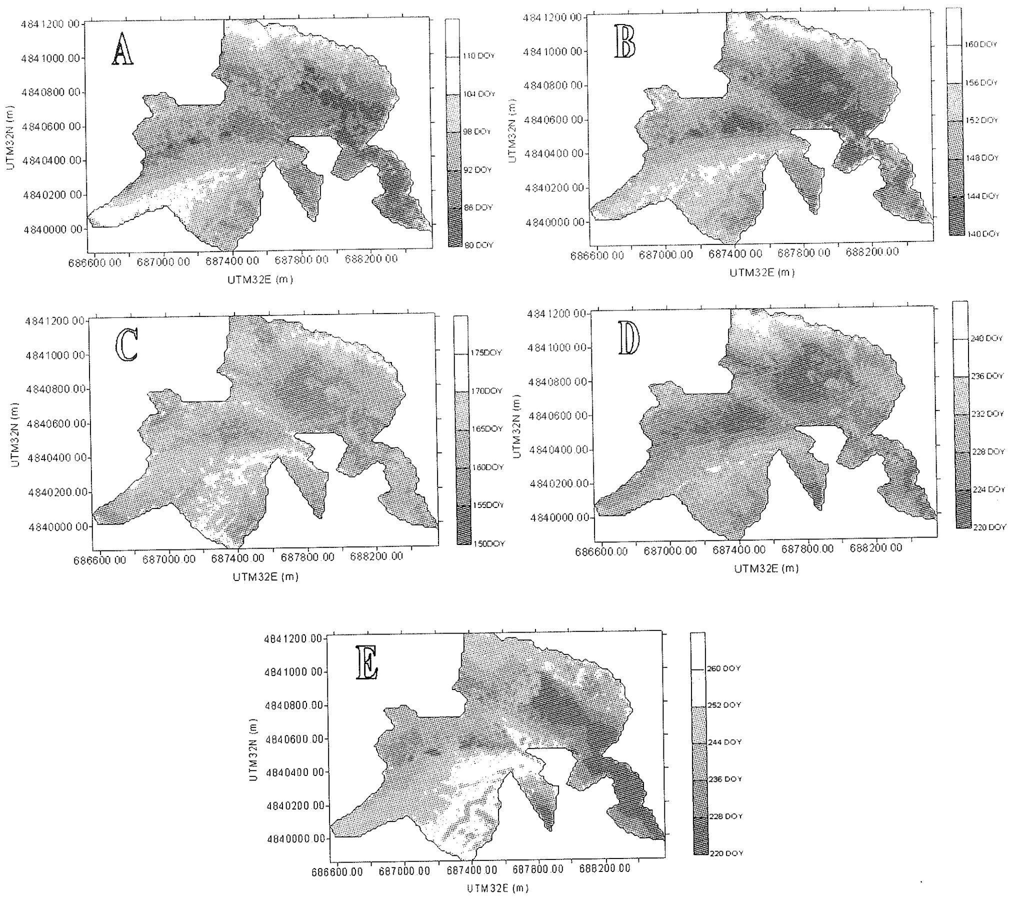

Figure 2: Neural network prediction of budbreak (A), bloom (B), onset of fruit growth (C) veraison (D) and maturity (E) dates for grapevine at local scale.

5 CONCLUSION

These results show that the up-scaling method based on neural network approach provides quite satisfactory estimates for both scales and a good accuracy in the representation of spatial patterns. This allows to describe the differences among areas and to emphasise the suitability of specific areas for high quality production.
Concerning the practical applications of this approach, it could be used to classify the different characteristics of environments for regional planning, or to improve cultivation techniques considering the actual phenophase variability of grapevine determined by topographic and geographic factors. Moreover the proposed methodology could be extended also for other crops, thus increasing the possible fields of operational application, such as agrometeorology, allergology, etc.

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COMPARISON OF PREDICTING FULL FLOWERING DATES OF APPLE TREE (*Malus domestica Borkh*) AND PLUM TREE (*Prunus domestica L.*) IN LJUBLJANA

PRIMERJAVA NAPOVEDOVANJA SPLOŠNEGA CVETENJA BOBOVCA (*Malus domestica Borkh*) IN DOMAČE ČEŠPLJE (*Prunus domestica L.*) V LJUBLJANI

Lučka Kajfež-Bogataj[1] and Klemen Bergant[2]

POVZETEK

V članku so obravnavane podobnosti med napovedovanjem splošnega cvetenja pri jablani (cv. 'bobovec') in splošnega cvetenja pri domači češplji. Analize podatkov so bile narejene na Centru za biometeorologijo, Biotehniške fakultete, Univerze v Ljubljani in temeljijo na podatkih fenoloških in klimatoloških opazovanj Hidrometeorološkega zavoda Republike Slovenije. Zaradi povezave med klimatskimi razmerami ter rastjo in razvojem rastlin, smo kot prediktorje splošnega cvetenja domače češplje in bobovca uporabili maksimalne in minimalne dnevne temperature zraka za prve štiri mesece (januar, februar, marec in april) v letih med 1969 in 1991 ter povprečne mesečne temperature zraka in količine padavin za iste štiri mesece za obdobje med 1967 in 1996. Poleg klimatoloških parametrov smo kot prediktorje splošnega cvetenja pri obravnavanih sadnih drevesih uporabili podatke o pojavu nekateri zgodnejših fenofaz samoniklih rastlin: pojav prvih listov pri brezi, bukvi in lipi ter začetek cvetenja španskega bezga. Za izdelavo modelov napovedovanja splošnega cvetenja domače češplje in bobovca smo uporabili dve metodi: linearno multiplo regresijo ter metodo temperaturnih vsot. Rezultati linearne multiple regresije kažejo, da lahko za napoved splošnega cvetenja bobovca s pridom uporabimo podatke o pojavu prvih listov pri bukvi ($R^2 = 0{,}55$), pri lipi ($R^2 = 0{,}62$) ter pri brezi ($R^2 = 0{,}73$). Podatki o pojavu prvih listov pri brezi so uporabni tudi za napovedovanje splošnega cvetenja domače češplje ($R^2 = 0{,}61$). Poleg tega obstaja statistično značilna zveza med pojavom splošnega cvetenja tako pri bobovcu kot pri domači češplji s kombinacijo povprečne marčevske in aprilske temperature zraka. V primeru napovedovanja splošnega cvetenja bobovca lahko s takšnim modelom razložimo 76 % variabilnosti podatkov v primeru splošnega cvetenja domače češplje pa 55 %. Vendar je napovedovanje splošnega cvetenja bobovca na podlagi povprečne marčevske in aprilske temperature zraka možno v povprečju le dva dni vnaprej, v primeru domače češplje pa še manj. Povezave pojava splošnega cvetenja bobovca in domače češplje s količino padavin v spomladanskem času niso statistično značilne. To lahko razložimo s tem, da v pomladanskem času količina padavin zadostuje potrebam rastlin. V drugem primeru smo s prirejeno metodo pravokotnika skušali oceniti efektivne temperaturne vsote nad različnimi temperaturnimi pragovi. Temperaturne vsote od prestopa praga do pojava splošnega cvetenja bobovca in domače češplje so bile izračunane za pragove med 0 in 10 °C s korakom 0,5 °C. Izmed uporabljenih temperaturnih pragov smo za napovedovanje fenofaze splošnega cvetenja pri obravnavanih sadnih drevesih po kriteriju minimalne relativne variabilnosti temperaturnih vsot med obravnavanimi leti izbrali: za bobovec temperaturni prag 6 °C ter za domačo češpljo 5,5 °C. Efektivna temperaturna vsota za pojav splošnega cvetenja bobovca tako v povprečju znaša 217 °C in je v dosežena 44 dni po prestopu temperaturnega praga 6 °C. V primeru domače češplje pa fenofaza splošnega cvetenja nastopi, ko je dosežena efektivna temperaturna vsota 233 °C, do česar v povprečju pride 45 dni po prestopu temperaturnega praga 5,5 °C. Tako v primeru uporabe linearne multiple regresijske metode kot metode temperaturnih vsot so podobnosti med modeli napovedovanja splošnega cvetenja bobovca in domače češplje očitne. Vzrok je najbrž v tem, da se sam fenološki razvoj pred splošnim cvetenjem pri obravnavanih sadnih drevesih, navkljub temu da pripadata različni rastlinski vrsti, ne razlikuje toliko kot fenološki razvoj po splošnem cvetenju. Razvoj plodu, ki se začne po koncu cvetenja, pri pečkarjih, kamor spada bobovec, poteka drugače kot pri koščičarjih, kamor spada domača češplja. Zato je pričakovati večje razlike med modeli v primeru napovedovanja pojava kasnejših fenofaz bobovca in domače češplje. Analize fenoloških podatkov, ki so predstavljene v članku, kažejo na to, da lahko za napovedovanje pojava fenofaz sadnega drevja uporabimo različne klimatološke podatke ter fenološke podatke samoniklih rastlin. Vendar pa moramo pri uporabi regresijskih modelov, kot tudi modelov s temperaturnimi vsotami, upoštevati da se, tako kot temperaturne razmere od pomladi do pomladi, tudi dolžina intervala, ko je dosežena ustrezna temperaturna vsota, iz leta v leto močno razlikuje.

Ključne besede: fenologija, statistični modeli, temperaturne vsote

ABSTRACT

Paper discusses the similarities in predicting the full flowering of apple tree and plum tree in Ljubljana. The study was conducted on University of Ljubljana, based on climatological and phenological observations of Hidrometeorological institute of Slovenia during the time period 1967-1996. Two different approaches were employed for predicting of full flowering of apple tree and plum tree. In first case the linear multiple regression technique was used. Input data for models were climatological data (average monthly air temperatures and average monthly amount of precipitation) and phenological data of autochthon plants. The date of flowering for both species is

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strongly correlated with first leaves unfolding of birch and in case of apple tree also with first leaves unfolding of linden and beech. Also strong correlation with combination of average March and April air temperature was found. In second case the modified rectangular method was used for calculating the accumulated degree-days. Input data were daily maximum and minimum temperature, and threshold temperature for calculating the degree-days totals. The threshold temperature was estimated by using different temperatures between 0 and 10 °C and choosing the one, which produce the lowest relative variability in accumulated degree-days. The estimated value for threshold temperature for apple tree is 6 °C and for plum tree 5.5 °C. The analyze shows that different climatological data and phenological data of autochthon plants could be successfully used for prediction of phenophases of different fruit trees.

Key words: phenology, statistical models, degree-days

1 INTRODUCTION

Climate conditions have great impact on plant growth and development. The most obvious indicator of relationship between climate variation and plant development is time of appearance of different phenophases. Phenological observations are the basis to study: the timing of recurring biological events, the causes of their timing with regard to biotic and abiotic forces, and the interrelation among phases of the same or different species (Lieth, 1974).

There are two main approaches to phenological data analyses: descriptive and quantified. The procedures of descriptive statistics are fairly straightforward, but in practice interpretations of results vary greatly between national agrometeorological services and also among scientists (Scharrer et al., 1998) On the other hand, modern phenological approaches base on quantifying the relations between phenological processes and environmental parameters or different biological processes. This comprises mainly phenological models, which are primarily designed to predict or understand the relationship between occurrence of biological event and another event or process (Hodges, 1991).

The aim of this paper is to compare the multiple regression models for prediction of flowering dates of apple tree (*Malus domestica* Borkh), which belongs to pome fruit trees and plum tree (*Prunus domestica* L.) which belongs to stone fruit trees. The multiple regression models used in this study base on climatological data (average monthly air temperature and precipitation) and phenological data of autochthon plants (birch–*Betula pendula* Roth, linden–*Tilia platyphyllos* Scop., beech–*Fagus sylvatica* L. and Spanish elder – *Syringa vulgaris* L.) for location Ljubljana. The possibility of estimation the threshold temperature (LTh) for calculating accumulated degree–days and using it for prediction of flowering days is also discussed in this paper.

2 MATERIAL AND METHODS

Climatological and phenological data for Ljubljana for time period 1967-1996 were used as input data. The used climatological data comprise the daily maximum (*Max*) and minimum (*Min*) air temperature for time period 1969-1991, average monthly air temperature (T_{month}) and average monthly amount of precipitation (RR_{month}) for time period 1967-1996, for months from January till April. From phenological data, dates of full flowering ($p_{F,specie}$) of apple tree (*Malus domestica* Borkh) and plum tree (*Prunus domestica* L.), unfolding of first leaves ($p_{L,specie}$) of birch (*Betula pendula* Roth), linden (*Tilia platyphyllos* Scop.) and beech (*Fagus sylvatica* L.), and beginning of flowering ($p_{B,specie}$) of Spanish elder (*Syringa vulgaris* L.) were used in our study. Hidrometeorological institute of Slovenia did the collection and quality check of data. Studied plant species are widely spread in Slovenia and some similar analyzes were already done also for other sites around country (Kajfež-Bogataj, 1997).

In first case the stepwise multiple regression technique (Zar, 1996) was employed to build phenological models for predicting $p_{F,apple}$ and $p_{F,plum}$ from earlier phenophases of autochthon species, and from average monthly air temperature and precipitation data. All calculations were performed using statistical package STATGRAPHICS Plus 2.1.

Plants require a certain amount of heat to develop from one point in their life–cycle to another (Wilson et al., Barnett, 1983). Accumulated degree-days (*DD*) are often used as heat measure in phenological modeling. The degree-day (*DD*) calculation methods differ somewhat in complexity (Wilson et al., 1983). Three methods are common: rectangular, triangular, and sin wave. All use *Max* and *Min* to try to estimate the *DD* total. Triangular and sine wave methods use curve fitting at half-day intervals. They are more accurate and done using a computer program. The rectangular method employs simple averaging, is less accurate, but usually provides adequate results; it can be done by hand, using data provided by maximum and minimum thermometers (Baskerville et al., 1969). In our case the modified rectangular method was used (Table 1).

Table 1: Relationship defining modified rectangular method for estimating of DD totals.

Modified rectangular method using only LTh	
IF	
Min>Lth	$DD = \frac{Max + Min}{2} - LTh$
Max>LTh Min<LTh	$DD = \frac{(Max - LTh)^2}{2(Max - Min)} - LTh$
Max<LTh	$DD = 0$

Max and *Min* data were used to determine the *LTh* for calculating *DD* for apple tree and plum tree. *DD* were calculated for *LTh* from 0 to 10 °C with step 0.5 °C and the threshold temperature, which produced minimum relative variability (Zag, 1996) in *DD* for 22 years (1969-1991), was chosen as the best.

3 RESULTS AND DISCUSION

The values of climatological parameters in Ljubljana vary from spring to spring and, therefore, the dates of different phenophases of fruit trees vary accordingly. Descriptive statistics about full flowering of apple tree and plum tree in years between 1967 and 1996 are presented in Table 2.

In average, the appearance of full flowering of plum tree is 4 days ahead of full flowering of apple tree. The expected day for full flowering of plum tree is 28th April and for full flowering of apple tree is 2nd May. The variability of full flowering date for plum tree is higher than for apple tree, which can bee seen from values of standard deviation in Table 2. The range for flowering date is in case of plum tree is also longer than in case of apple tree for about 43 %.

Table 2: Descriptive statistics of full flowering date of apple tree and plum tree in Ljubljana in years from 1967 to 1996.

	plum tree	apple tree
average p_F	118th day 28. April	122th day 2. May
latest p_F	132th day 12. May	134th day 14. May
earliest p_F	92th day 2. April	106th day 16. April
variation range	40 days	28 days
standard deviation	9.5 days	6.6 days

The correlation analyzes were performed to find the relationships between the full flowering of plum and apple tree and climatological parameters and also between full flowering and appearance of some phenophases of autochthon plant species. The correlation coefficients for individual predictor are presented in Table 3 and Table 4.

Table 3: Correlation coefficients for predicting the full flowering date of plum and apple tree on the base of climatological data.

	$T_{January}$	$T_{February}$	T_{March}	T_{April}	RR_{Januar}	$RR_{Februar}$	RR_{March}	RR_{April}
$p_{F,plum}$	- 0.28	- 0.52	- 0.59	- 0.40	0.22	- 0.05	0.30	0.02
$p_{F,apple}$	0.00	- 0.45	- 0.64	- 0.33	0.40	- 0.05	0.27	0.19

Table 4: Correlation coefficients for predicting the full flowering date of plum and apple tree on the base of autochthon plant species development indices.

	$p_{L,birch}$	$p_{L,beech}$	$p_{L,linden}$	$p_{B,elder}$	$p_{F,plum}$	$p_{F,plum}$
$p_{F,plum}$	0.78	0.62	0.65	0.54	1	0.65
$p_{F,apple}$	0.86	0.77	0.79	0.44	0.65	1

The results of correlation analyze show, that here is no significant correlation between p_F of studied fruit trees and individual T_{month}. The stepwise correlation method (Zar, 1996) was performed to check, if there are combinations of different climatological parameters that influence on appearance of full flowering of apple tree and plum tree. In both cases the combination of T_{March} and T_{April} was found to be important for predicting the p_F.

In case of RR_{month} the situation is even worse than in case of individual T_{month}. The p_F were not correlated to RR_{month} at all. This could be expected since in Slovenia, water availability in the spring is not a major problem and air temperature plays decisive role in determining phenological development (Kajfež-Bogataj et al., 1998).

For both studied fruit trees, the p_F is strongly correlated with $p_{L,birch}$ and in case of apple tree also with $p_{L,linden}$ and $p_{L,beech}$. The correlation coefficient in mentioned cases were higher than 0.7, which means, that more than half of variance, can be explained by linear model between p_F and mentioned phenophases of autochthon trees. Statistical models for predicting the $p_{F,apple}$ and p_{Fplum} on the base of T_{March}, T_{April}, $p_{L,birch}$, $p_{L,linden}$, and $p_{L,beech}$ are presented in Table 5 and Table 6.

Table 5: Linear simple regression models for predicting the $p_{F,apple}$ and $p_{F,plum}$ on the base of phenological data of some autochthon species.

MODELS BASED ON DIFFERENT PLANTS PHENOLOGY		
STATISTICAL MODEL	R^2	days ahead
$p_{F,plum} = 0{,}88 \times p_{L,birch} + 22.6$	0.61	15
$p_{F,apple} = 0{,}68 \times p_{L,birch} + 43.2$	0.73	13
$p_{F,apple} = 0{,}67 \times p_{L,linden} + 47.4$	0.62	11
$p_{F,apple} = 0{,}93 \times p_{L,beech} + 19.2$	0.55	11

Table 6: Linear multiple regression models for predicting the $p_{F,apple}$ and $p_{F,plum}$ on the base of climatological data.

MODELS BASED ON MEAN MONTHLY AIR TEMPERATURES		
STATISTICAL MODEL	R^2	days ahead
$p_{F,plum} = -2.86 \times T_{March} - 3.92 \times T_{April} + 173$	0.55	0
$p_{F,apple} = -2.46 \times T_{March} - 3.30 \times T_{April} + 168$	0.76	2

In case of using $p_{L,birch}$ data as a predictor for $p_{F,apple}$ and $p_{F,plum}$ the predictions can be made 13 and 15 days ahead and in case of using $p_{L,linden}$ and $p_{L,beech}$ as a predictor for $p_{F,apple}$ 11 days. The multiple regression model for predicting the p_F on the base of

T_{March} and T_{April} have great disadvantage, because the predictions can be made in case of apple tree only 2 day ahead and in case of plum tree not even that. On the other hand, the similarity of multiple regression models for both trees shows us, that they have similar *LTh*.

Regarding the correlation coefficients in Table 3, we have chosen for the target interval for *LTh* values between $T_{Februar}$ (1.4 °C) and T_{April} (9.9 °C). We were trying to find the *LTh*, which would produce the minimum interannual variability of *DD* on chosen interval. The interannual variability of *DD* for apple tree and plum tree by using *LTh* from 0 to 10 °C with step 0.5 °C is presented on Figure 1. For measure of *DD* variability the coefficient of variation (*CV*) was used. In case of apple tree it reaches its local minimum value (7.3 %) between T_{March} and T_{April} at *LTh* 6 °C and in case of plum tree (11.9 %) at *LTh* 5.5 °C. The final model parameters are so for apple tree *LTh* 6 °C and *DD* 217 °C and for plum tree *LTh* 5.5 °C and *DD* 233 °C. Accumulation of *DD* starts for apple tree after the average daily temperature 6 °C threshold interception and reaches the value of 217 °C in average after 44 days. For plum tree the *DD* accumulation starts after 5.5 °C threshold interception which appears in average 45 days ahead of full flowering of plum tree, when the DD reaches value of 233 °C.

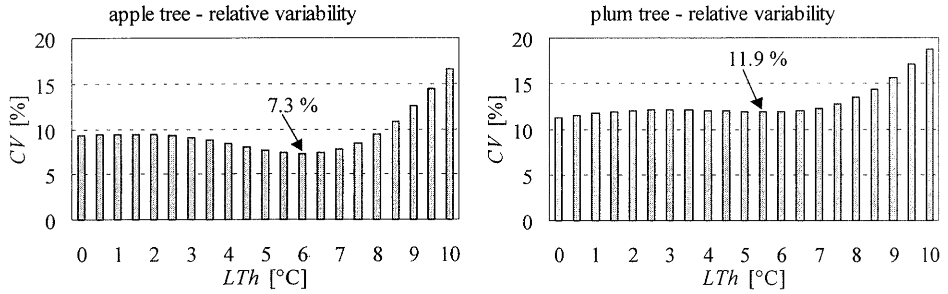

Figure 1: The interannual variability of *DD* for apple tree and plum tree for time period 1969-1991 by using different *LTh*.

In both types of models, the regression and *DD* models, we need to be aware that as the temperature conditions differ from spring to spring also the time interval for accumulation of *DD* and so the appearance of full flowering varies strongly from year to year.

4 CONCLUSIONS

The air temperature conditions in spring play decisive role in plant growth and development. Air temperature data and phenological data of earlier phenophases of autochthon plant species can be used to predict the appearance of full flowering of apple tree and plum tree in Ljubljana and also in other sites in Slovenia (Kajfež-Bogataj, 1997 and Kajfež-Bogataj et al., 1998). The best predictor for full flowering of apple tree and plum tree was in our case the unfolding of first leaves of birch tree. In case of apple tree the full flowering date can be predicted also on the base of first leaves unfolding of linden and beech. Also strong correlation was found between full flowering of both studied fruit trees and combination of T_{March} and T_{April}. Unfortunately the models based on this correlation are practically useless for predicting the date of full flowering, because they can not be used more then 2 days ahead. Monthly amounts of precipitation in spring can not serve as a predictor for full flowering of apple tree and plum tree.

Beside climatological data and phenological data of autochthon plant species also models based on previous phenophases of studied fruit trees can be produced (for example Kajfež-Bogataj, 1997 and Kajfež-Bogataj et al. 1998). In general the appearance of full flowering of stone fruit trees is earlier than of pome fruit trees. So it is not surprising, that the full flowering date of plum (*Prunus domestica* L.), which belong to stone fruit trees, is in average 4 days ahead of full flowering date of apple tree (*Malus domestica* Borkh), which belong to pome fruit trees.

Multiple regression models and degree-days models are very similar for both studied fruit trees, although we are dealing with different species. The reason is probably, that the phenological development before the phenophase of full flowering is not so different for studied fruit trees as after it. More significant difference between stone fruit trees and pome fruit trees is in case of fruit development, so some differences in prediction models for later phenophases are not excluded.

In our case only statistical models were used. They are very simple to derive, but unfortunately they are site specific. Further work should be done in direction of developing the dynamical phenological models that are more sound and of more general use.

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USAGE OF PHENOLOGICAL DATA BY DETERMINATION OF ALLERGENIC PLANTS POLLINATION

UPORABA FENOLOŠKIH PODATKOV PRI DOLOČANJU PRAŠENJA ALERGENIH RASTLIN

Andreja Sušnik[1] and Andreja Kofol-Seliger[2]

POVZETEK

Na osnovi dolgoletnih fenoloških podatkov alergenih rastlin (za obdobje 1980-1996), ki so zbrani v arhivu Hidrometeorološkega zavoda Republike Slovenije, so bili analizirani pojavi fenoloških faz v slovenskem prostoru. Preučevane so bile možnosti uporabe fenoloških podatkov za ugotavljanje obdobja cvetenja alergenih rastlin v območjih, kjer se meritve peloda ne izvajajo. V članku so bili obravnavani fenološki podatki za 150 fenoloških postaj, ki so delovale v obdobju 1980-1996. Razdelili smo jih v 15 geografsko-fenoloških regij. V analizo smo vključili podatke o pojavu fenološke faze *začetek cvetenja* za tri alergene rastline: leska (*Corylus avellana*), jelša (*Alnus glutinosa*) in breza (*Betula pendula*).

Zaradi iskanja določenega sinhronizma med pojavom fenološke faze in začetkom sezone pojava peloda smo uporabili podatke o pojavu peloda izbranih rastlin za območje Ljubljane za obdobje 1996-1998. Meritve pojava peloda izvaja Inštitut za varovanje zdravja v Ljubljani s pomočjo Hirstovega volumetričnega lovilca peloda (Burkart). Povprečna dnevna koncentracija peloda je izražena v številu pelodnih zrn v kubičnem metru zraka.

Pri analizi smo uporabili postopek ocene časovnega zamika cvetenja (pozitiven ali negativen zamik izražen v številu dni) po regijah v primerjavi z referenčno postajo Ljubljana na osnovi dolgoletnih povprečij. Primerjava fenoloških podatkov in podatkov o pojavu peloda za Ljubljano za obdobje 1996-1998 je pokazala, da z beleženjem fenološke faze cvetenja lahko ocenimo pojav peloda v zraku.

Na osnovi tega lahko trdimo, da je dolgoletno povprečje pojava fenoloških faz dober indikator za ugotavljanje potencialnega obdobja pojava peloda v zraku za regije, kjer še ni vzpostavljen monitoring peloda. Vendar pa moramo upoštevati, da je to le eden izmed načinov ugotavljanja začetka sezone pojava peloda v regiji, ne pa razporeditve peloda v sezoni, ki pa je pogojena izključno z vremenskimi razmerami.

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Ključne besede: alergene rastline, cvetenje, fenologija - *Corylus avellana*, *Betula pendula*, *Alnus glutinosa*

ABSTRACT

Phenological data of blossoming of allergenic plants provide useful information about pattern of pollen appearance for the places where measurements of pollen are not available.

The analysis was performed in order to relate the beginning of pollen season of specific plant and phenological stage: start of blossoming of four plants species: hazel (*Corylus avellana*), alder (*Alnus glutinosa*) and common silver birch (*Betula pendula*). An approach assuming that there is a certain sinhronism between phenological data: start of blossoming and the pollen season for the specific plants was made. Therefore the times of pollination for chosen plants over 3-years period (1996-1998) in Ljubljana were compared with the phenological data. Data for pollen were recorded and analysed by Slovenian Institute of Public Health.

The procedure we followed consists in the assessment of chronological delays of blossoming (number of days of delay or advance) of the regional phenological event due to the standard phenological station in Ljubljana.

An analysis was performed on the phenological data collected in the period 1980-1996 on the 150 phenological stations in Slovenia. The data concern the flowering of three chosen plants and blossoming patterns for Slovenia was made. The phenological data of blossoming could be helpful to indicate the beginning of pollen season in regions where data of pollen appearance are not available.

Key words: allergenic plants, pollination, phenology - *Corylus avellana*, *Betula pendula*, *Alnus glutinosa*

1 INTRODUCTION

One of the most obvious features of pollen allergy is its seasonal nature-people experience it occurs only when the specific pollen grains are in the air. Each plant has a pollinating period that is more or less the same from year to year.

The occurrence of phenological phase (phenophase) is dependent on both the biotic characteristics of plant species and the climatic characteristics of the situation in which the species lives (Puppi Branzi and Zanotti, 1992).

Each step of the aerobiological pathway (emission, dispersion and deposition or impact) is linked to different biological phenomena that are governed by different meteorological factors. It must be noted also that the meteorological factors may have different effects (Comtois and Sherknies, 1987). This makes the situation very complex. So the shapes of the pollen curves do not always agree with floral development (Lattore, 1997).

It is very important to know blooming periods to correlate with the corresponding aerobiological curves (Zerboni et al., 1986). Flowering calendars are useful but they do not take into account the intensity of the emission (Lattore, 1997).

The long-term data of flowering has marked interannual variability owing to weather conditions. In spite of that it shows us potential period in which the pollen onset is very probable. Phenological data are the base, and in some cases the only empirical support to interpret atmospheric pollen data.

The aim of this paper was to analyse the regional distribution of blossoming of some allergenic plants in Slovenia for the period 1980–1996. Data for pollen appearance and distribution for the same plants in Ljubljana town were compared with the phenological data for the period 1996-1998. This pattern was used as an indicator for the pollen appearance in the places where pollen monitoring is not available.

2 MATERIAL AND METHODS

2.1 POLLEN CONCENTRATION MEASUREMENT

In Slovenia a study of the pollen appearance is carried out by the Slovenian Institute of Public Health and the Internal Clinic Golnik - Department for pulmonary diseases and allergies. The study is involved in the framework of the projects of Ministry of Science and Technology and co-financing from the Ministry of Health. Hydrometeorological Institute is taking part with the meteorological and phenological data and by the interpretation of data.

The sampling of the airborne pollen seven-days volumetric Hirst type spore trap (Burkart) is used (Seliger, 1997). It is placed on the roof of Hydrometeorological Institute of Slovenia in Ljubljana. The pollen concentration is registered continuosly in 2-hours intervals. Average daily pollen concentration of different kinds of plants in the atmosphere is expressed in terms of the number of pollen grains per cubic meter of air (Seliger,1997). The pollen trap is changed three times per week, in the season daily. The samples are prepared and the results interpreted according to the standard method recommended by the International Association for Aerobiology. They are following up the most significant allergic sorts of pollen according to the recommendation of

Subcommittee for Aerobiology of ECACI (European Congress of Alergology and Clinical Immunology), accepted in Madrid in 1995.

Selection of taxa:
- required minimal selection:
Alnus, Corylus, Cupressaceae, Taxaceae, Betula, Poaceae (Gramineae) (including Cerealia), Olea, Urticaceae, Artemisia, Ambrosia.
- further selection (recommended):
Fraxinus, Platanus, Pinus, Quercus, Castanea, Rumex, Plantago.
The measurements up to now are available only for Ljubljana region.

The data available for this analysis originate from the observations on daily pollen concentrations of hazel (Corylus), alder (Alnus) and birch (Betula) in Ljubljana over a period of three years (1996-1998). We chose plants triggering the most early allergenic symptoms. Data of daily concentration of specific pollen are presented for each year separately.

Figure 1: Hirst volumetric pollen trap (Photo: A. Kofol-Seliger).

2.2 BLOSSOMING OF ALLERGENIC PLANTS OBSERVED ACCORDING TO THE PHENOLOGICAL PROGRAM OF THE HYDROMETEOROLOGICAL INSTITUTE

In order to trace a relationship between phenological phenomena and pollen appearance the starting dates of the flowering of hazel, alder and birch for the period 1980-1996 were used. We included all phenological stations with available data for the selected species. For the Ljubljana station we used also data for the years 1996-1998.

We divided all the stations to 15 geographical-phenological regions. Number of stations per region was different from the region to region likewise the number of phenological objects on the specific phenological station and the time of observing period (see table 1).

For the phenological data within region we calculated average dates of blossoming appearance for chosen plants with average maximum and minimum values in the region.

Table 1: Number of the phenological objects by regions in Slovenia.

Region	**alder**	**common silver birch**	**hazel**
Idrijsko-Cerkljansko region	2	6	6
Bela Krajina region	2	3	3
Dolenjska region	3	6	7
Drava valley, Carinthia and Pohorje borders	7	9	9
the borders of Julian Alps and Karavanken Mountains	1	15	15
Karst and Brkini region	1	1	5
the borders of Ljubljana basin	5	6	6
Notranjsko-Kočevska region	6	11	11
Littoral, Slovenian Istra and Vipavsko-Goriška region	3	2	5
Podravje region	4	4	3
Pomurje and Goričko region	4	4	5
Savinja valley with Celje	9	8	11
Slovenske Gorice region	4	5	5
Soška valley up to Kobarid	5	7	8
lower part of Krka river	2	5	7
Σ	58	92	106

According to the phenological program of HMI we observe phenological phase first blossoms appearance which is registered when first male catkins start to blossom.

3 RESULTS AND DISCUSSION

3.1 COMPARISON BETWEEN PHENOLOGICAL DATA OF ALLERGENIC PLANTS AND POLLEN APPEARANCE IN LJUBLJANA IN THE PERIOD 1996-1998

In the first part of the analysis we compared the blossoming onset of selected plants with the pollen appearance in Ljubljana for the years 1996, 1997 and 1998. In the figures daily distribution of pollen for single year are presented.

Hazel

In the Figure 5 it is obvious that from March 11 till March 20 only few pollen grains of hazel were registered in Ljubljana in 1996. The blossoming stage of hazel according to the phenological program was recorded on March 16. March 20 was the day when the amount of pollen grains in the air increased. On March 21 the seasonal peak of pollen grains was recorded (88 grain in m^3 of air). In the Figure 6 the situation for the year 1997 is presented. Flowering in this year started very early, in February. The phenological date is February 16. Some pollen grains appeared in the air already in the first days of February. The quantity of hazel pollen in the year 1997 was not as evident as in the year 1996. The highest number was 22 grains of pollen per m^3. In 1998 warm January resulted in very early appearance of hazel pollen in the air. This year the peaks of mean daily concentrations of hazel were higher than in 1997 (on February 15 cca 700 pollen grains in m^3 of air were registered).

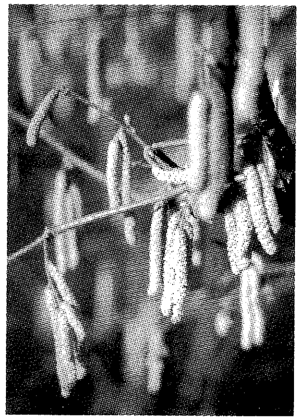

Figure 2:
First blossoms of hazel (*Corylus avellana*).

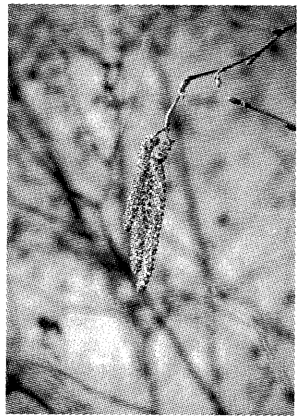

Figure 3:
First blossoms of alder (*Alnus incana*).

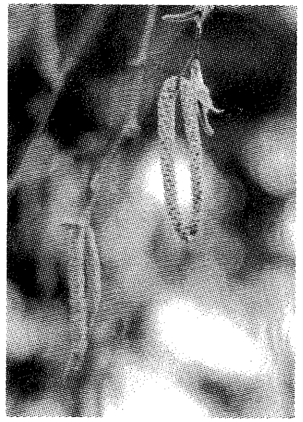

Figure 4:
First blossoms of common silver birch (*Betula pendula*).

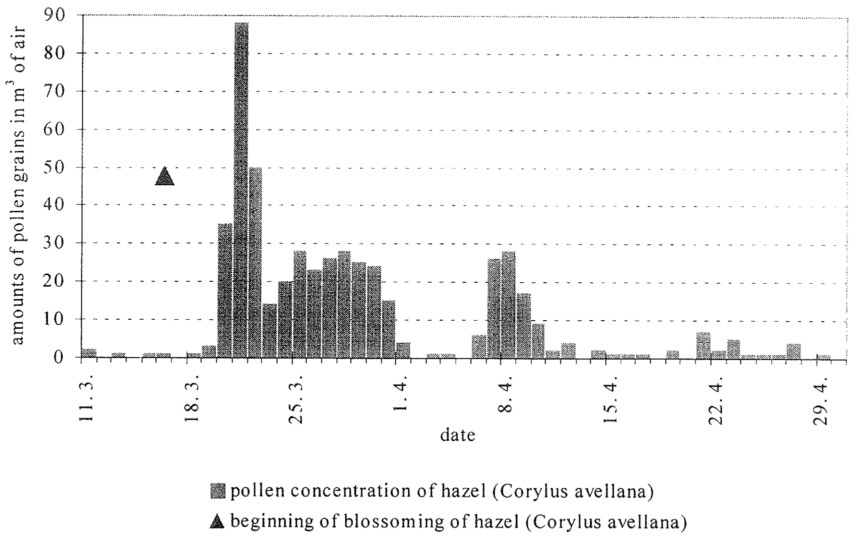

Figure 5: Daily concentration of hazel pollen grains in 1996 and date of phenological stage: *start of blossoming* of hazel at the phenological station Ljubljana in 1996.

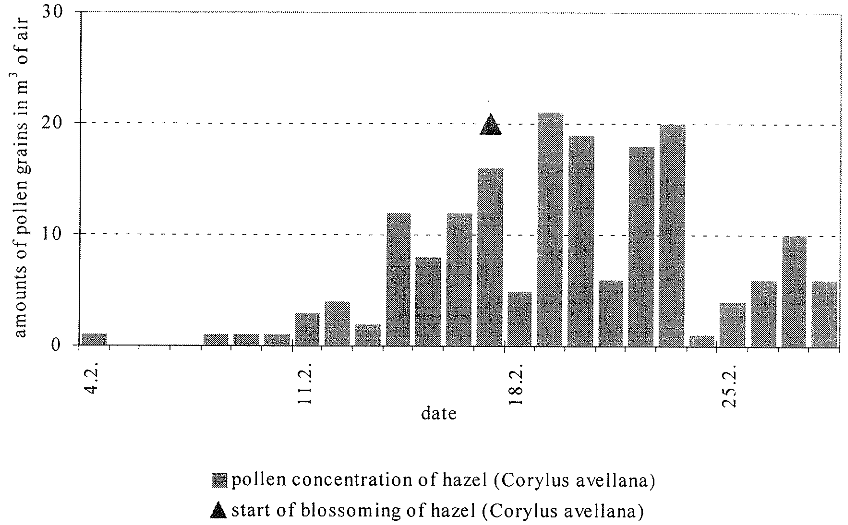

Figure 6: Daily concentration of hazel pollen grains in 1997 and date of phenological stage: *start of blossoming* of hazel at the phenological station Ljubljana in 1997.

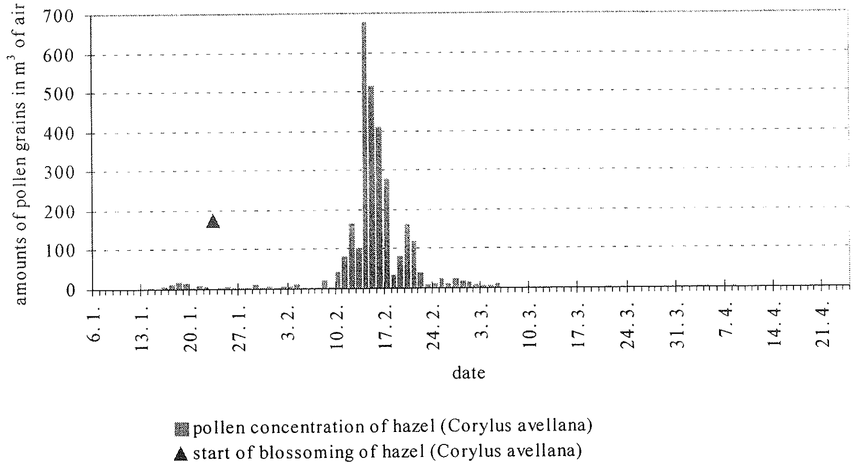

Figure 7: Daily concentration of hazel pollen grains in 1998 and date of phenological stage: *start of blossoming* of hazel at the phenological station Ljubljana in 1998.

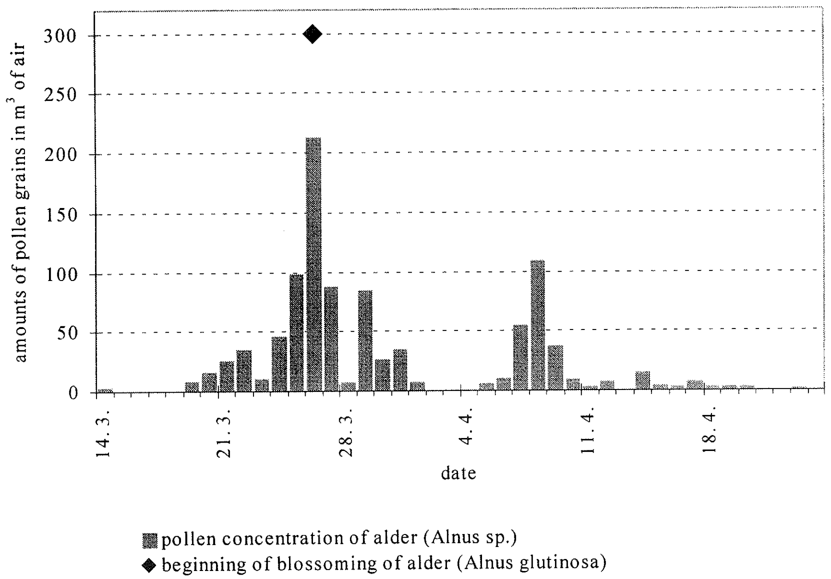

Figure 8: Daily concentration of alder pollen grains in 1996 and date of phenological stage: *start of blossoming* of alder at the phenological station Ljubljana in 1996.

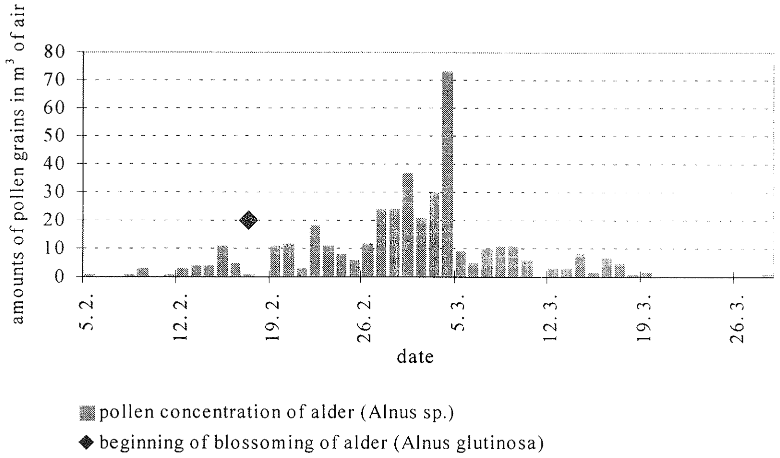

Figure 9: Daily concentration of alder pollen grains in 1997 and date of phenological stage: *start of blossoming* of alder at the phenological station Ljubljana in 1997.

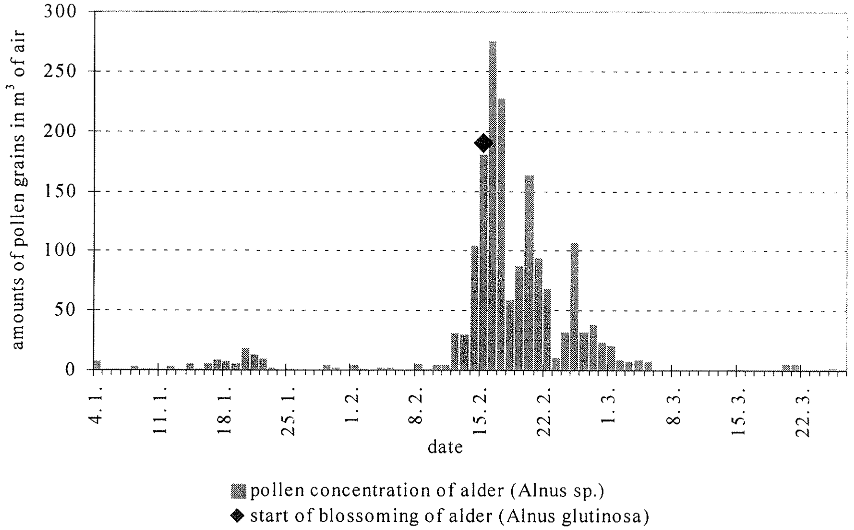

Figure 10: Daily concentration of alder pollen grains in 1998 and date of phenological stage: *start of blossoming* of alder at the phenological station Ljubljana in 1998.

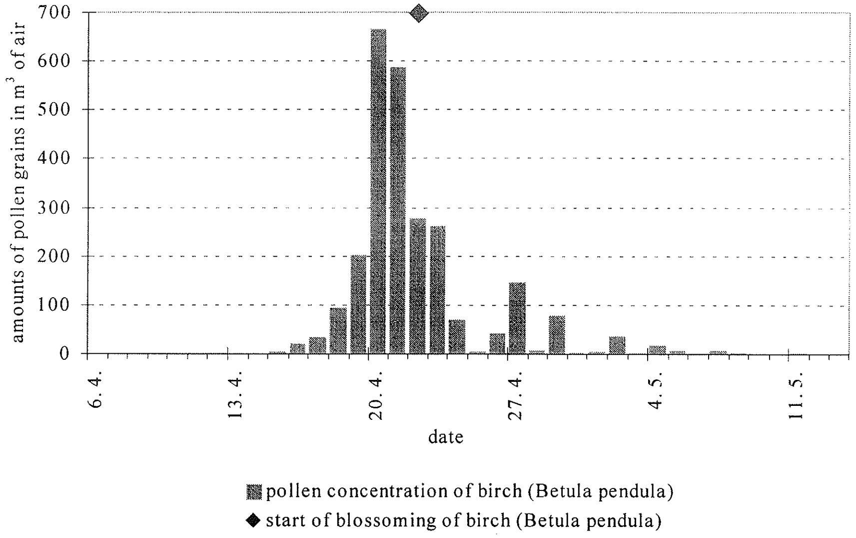

Figure 11: Daily concentration of birch pollen grains in 1996 and date of phenological stage: *start of blossoming* of birch at the phenological station Ljubljana in 1996.

Alder

In 1996 the alder started to blossom on March 26 and the same day the maximum amount of pollen was registered in Ljubljana (213 grains of pollen in m^3 of air). The pollen appearance in smaller concentrations was recorded already from March 14. This was probably because Alnus incana blossoms before Alnus glutinosa and pollen determination is not easy to differentiate. In 1997 alder blossomed on February 17. The first pollen (10 grains in m3 of air) appeared since February 5. In the year 1998 phenological stage of blossoming was registered the day before the maximum concentration of alder pollen was recorded (on February 15).

Common silver birch

The birch showed the greatest difference between phenological data and pollen appearance. In 1996 and 1998 the birch pollen appeared earlier than the onset of blossoming. In 1996, after the peak of pollen concentration has already been reached on April 22, the phenophase was registered. Only in the year 1997 the blossoming was registered one day before the maximum concentration of pollen in the air was registered. The reason is probably inaccurate phenological data or determination of phenological phenophase is not defined well.

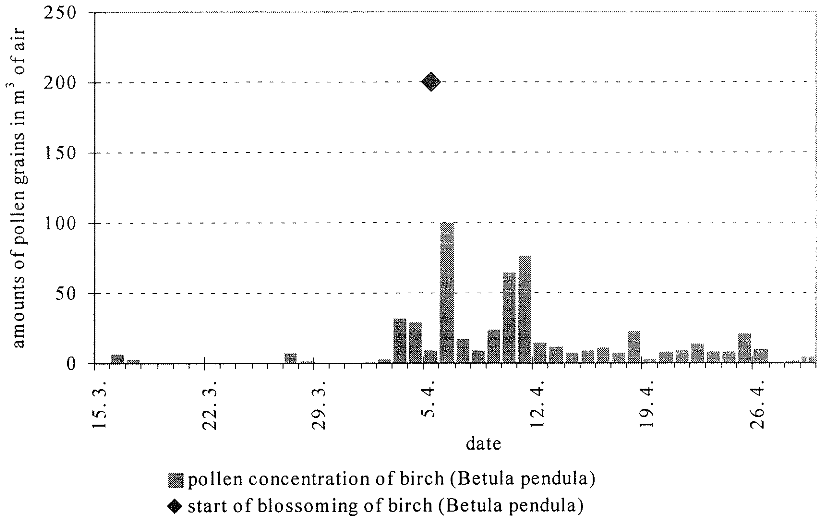

Figure 12: Daily concentration of birch pollen grains in 1997 and date of phenological stage: *start of blossoming* of birch at the phenological station Ljubljana in 1997.

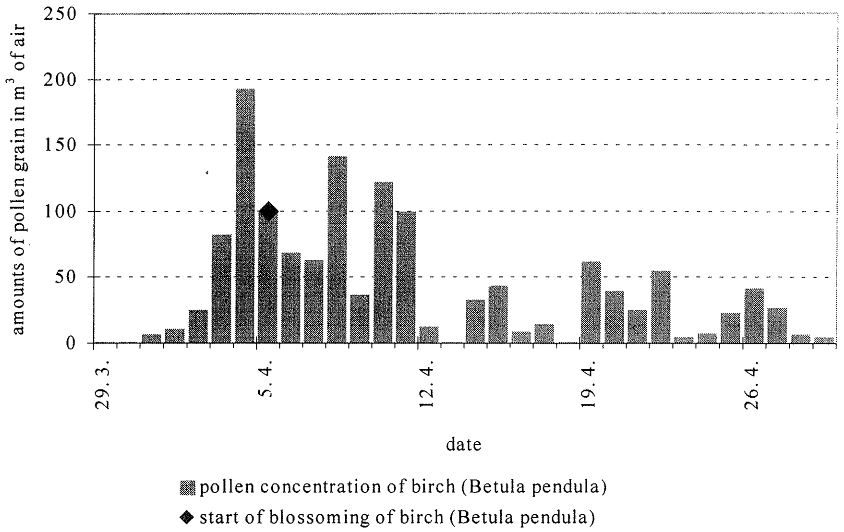

Figure 13: Daily concentration of birch pollen grains in 1998 and date of phenological stage: *start of blossoming* of birch at the phenological station Ljubljana in 1998.

3.2 PHENOLOGICAL DATA OF ALLERGENIC PLANTS BY DETERMINATION OF POLLEN APPEARANCE IN SLOVENIA

In applied aerobiology much attention is payed to the approaches of airborne pollen concentration forecasting for the area with no data available. Therefore it is necessary to obtain detailed informations on the pollen sources (allergenic plants) blossoming on the specific area.

At the moment in Slovenia only data for pollen appearance for Ljubljana are available. In the first part of analysis we found out that there is a specific synchronism with the first blossoms onset and the pollen appearance for the phenological station Ljubljana.

Information on the variations of the allergenic plants blossoming in Slovenia in space and time may be obtained from the figures of phenological delays (number of days of delay or advance: in the last case values are negative) of the collective event of phenophase inside the 15 regions with regard to reference station Ljubljana.

An application of a method for obtaining phenological delay for three phenological objects for 15 regions in Slovenia is illustrated in the Figure 14, 15 and 16.

Hazel

It is interesting to note that blossoming in the urban areas like in Ljubljana on average begin even earlier than on the sunny slopes of the hills Slovenske Gorice. Two days earlier than in Ljubljana blossoming of hazel started in Podravje region (stations Starše, Maribor, Podlehnik at the elevation 240 to 350 m). The earliest appearance was in the Littoral, Slovenian Istra and Vipavsko-Goriška region (-15 days). The latest onset of blossoming was recorded on the borders of Julian Alps and Karavanken Mountains (from 400 m up to 900 m a.s.l.), in Idrijsko - Cerkljansko region (stations from 600 to 700 m a.s.l.) and in Notranjsko-Kočevsko region (from 500 to 800 m a.s.l.). On average in all these regions hazel blossomed 16 to 17 days later than in Ljubljana. In all other regions phenophase of hazel blossoming started 5 to 8 days later than in our capital.

Alder

Figure 15 represents delays for the alder. In this case the deviation of data from the standard is very high. In the borders of Julian Alps and Karavanken Mountains (data for 10 stations), Idrijsko-Cerkljansko region (at the elevation 600 m data for two sites were available), Notranjsko-Kočevska region (stations from 500 to 700 m a.s.l.) deviated from the standard on average for 24 to 27 days. Very similar and for this region untypical is the situation in Dolenjska region - the delay is +26 days. Namely two stations are sited on the hills (Višnja gora, Grm pri Radohovi vasi). The earliest

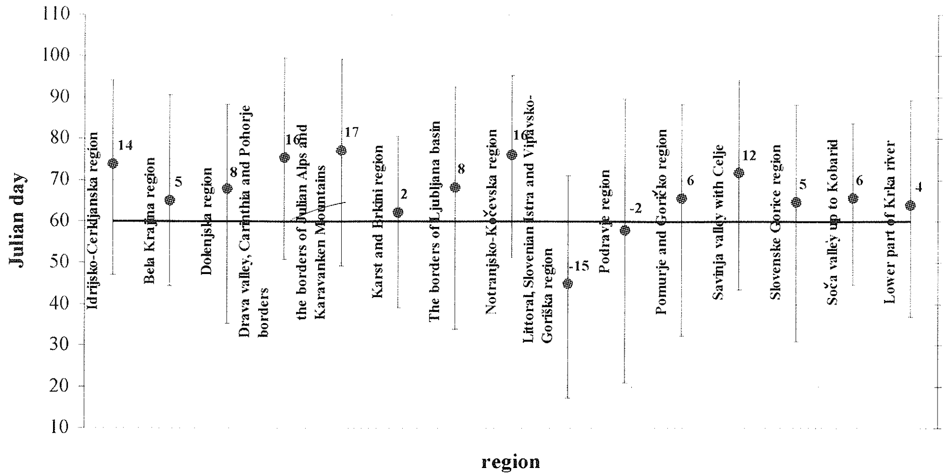

Figure 14: Phenological delay (number of days of delay or advance: in the last case values are negative) of the regional event of phenophase: *blossoming of hazel* inside the 15 regions with regard to a reference station Ljubljana.

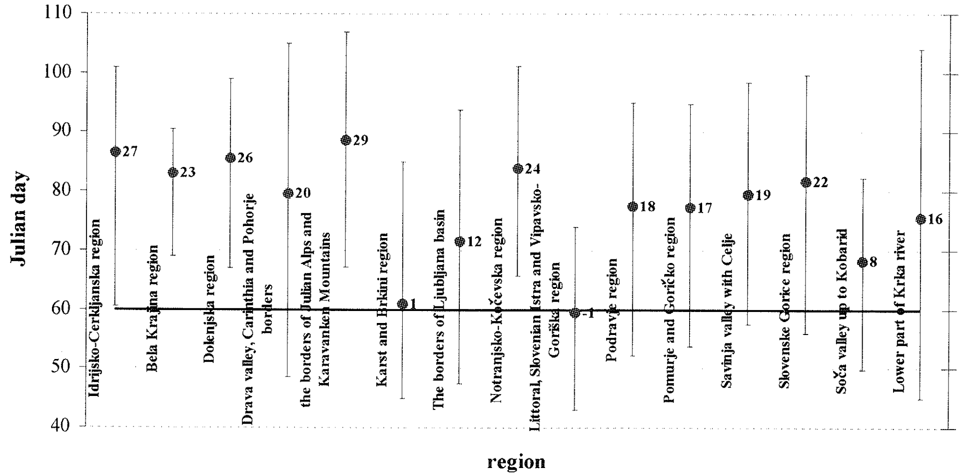

Figure 15: Phenological delay (number of days of delay or advance: in the last case values are negative) of the regional event of phenophase: *blossoming of alder* inside the 15 regions with regard to a reference station Ljubljana.

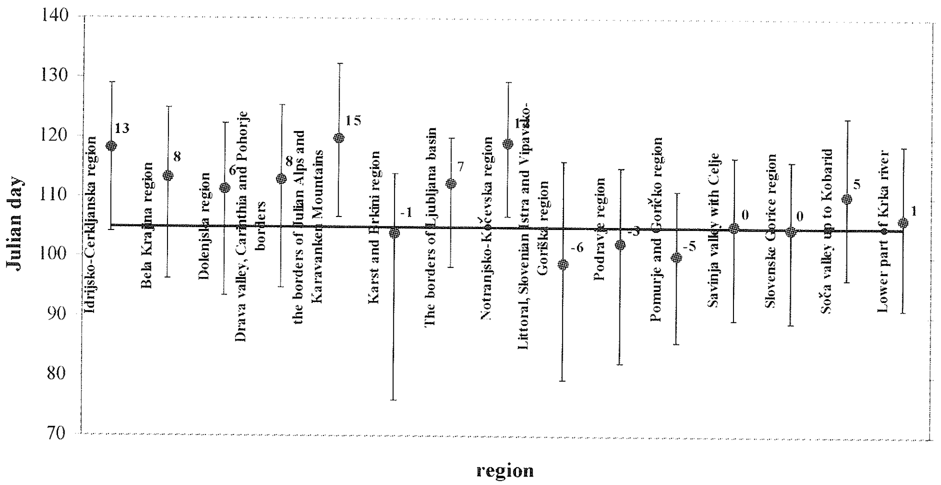

Figure 16: Phenological delay (number of days of delay or advance: in the last case values are negative) of the regional event of phenophase: *blossoming of common silver birch* inside the 15 regions with regard to a reference station Ljubljana.

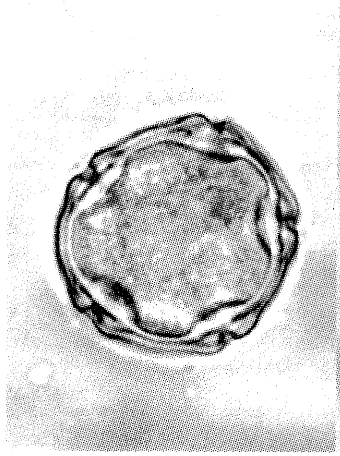

Figure 17:
Pollen of alder (*Alnus*).

Figure 18:
Pollen of hazel (*Corylus*).
(Photos: A. Kofol-Seliger)

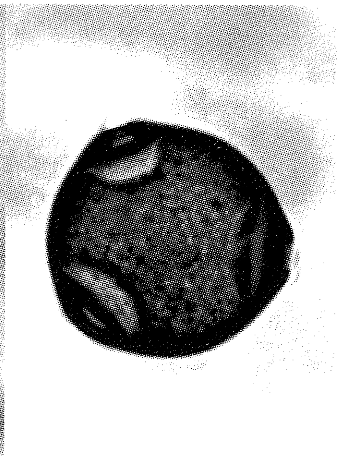

Figure 19:
Pollen of birch (*Betula*).

appearance was observed in Goriška region (-1). In most of other regions delay was from +8 to +19 days.

The high value of delay could be explained with the position of observed alder in Ljubljana. The location is nowadays completely surrounded with buildings and therefore the location is warmer and the onset of phenophase is probably because of that earlier.

Common silver birch

In Figure 16 delays for birch are presented. It shows similar pattern as figure for hazel. In Karst and Brkini region birch blossomed a day before it was registered in Ljubljana on average. In Podravje, Pomurje and Goričko region and in Littoral silver birch started to blossom 3 to 6 days earlier. The maximum delay registered was in the borders of Julian Alps and Karavanken Mountains (+15 days).

4 CONCLUSIONS

The paper deals with the ways of using various kinds of phenological data in alergology. The identification of the various flowering phases and additional information allow the users to obtain a "forecast" for the first blossoms appearance of allergenic plants for the regions where monitoring of pollen is not available.

This approach involves phenological data gathered over several years in defined areas. Data for pollen counts are at the moment available only for Ljubljana for three years and any conclusion for wider area of Slovenia is not possible.

In this analysis an attempt has been made to show as accurate as possible the start of blossoming season of allergenic plants with regard to a reference situation in Ljubljana.

We consider that this method is useful to compare the beginning of blossoming time in retrospect. But not so suitable to determine the start and distribution of pollen season which is more weather dependent. This analysis is purely statistical and does not include meteorological parameters, but applying instead long-term data sets of phenological data.

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EVALUATION OF WMO RA VI. AGROMETEOROLOGICAL QUESTIONNAIRE RELATED TO PHENOLOGICAL OBSERVATIONS AND NETWORKS

VREDNOTENJE WMO RA VI. AGROMETEOROLOŠKE ANKETE – FENOLOŠKA OPAZOVANJA IN MREŽE

Attila Bussay[1]

POVZETEK

Na anketo WMO RA VI. se je odzvalo 28 držav ter mednarodni center (EU - Joint Research Centre). Omenjeno število držav predstavlja 57 % vseh članic RA VI. (Regional Association). Od 28 ima kar 22 (79 %) držav vzpostavljeno mrežo fenoloških opazovanj: Armenija, Avstrija, Češka republika, Estonija, Francija, Hrvaška, Irska, Italija, Latvija, Litva, Madžarska, Makedonija, Moldavija, Nemčija, Romunija, Rusija, Slovaška, Slovenija, Španija, Švica in EU (JRC). Mreža fenoloških opazovanj ni vzpostavljena v Belgiji, Bosni in Hercegovini, Danski, Luksemburgu, Portugalski ter Združenem kraljestvu. S fenološkimi opazovalnimi mrežami večinoma upravljajo državne meteorološke oziroma hidrometeorološke službe. Prve mreže fenoloških opazovanj datirajo v dvajseta leta tega stoletja, večina opazovalnih mrež pa je bila vzpostavljenih v štiridesetih in petdesetih letih. Nekaj je tudi mlajših. Gostota opazovalnih mrež se med državami močno razlikuje. V splošnem mreže fenoloških opazovalnih postaj zajemajo dve vrsti postaj: postaje, kjer se opazuje fenološke faze gojenih rastlin ter postaje, kjer se opazuje pretežno negojene rastline. Večinoma so fenološke postaje vezane na farme, sadovnjake ter klasične meteorološke postaje. Nekaj pa je tudi eksperimentalnih postaj. Približno 61 % opazovalcev na fenoloških postajah opravlja delo profesionalno. V treh četrtinah obravnavanih držav potekajo opazovanja celo leto. Opazovanja so v rastni dobi bolj pogosta, navadno vsake dva dni, ponekod pa je razmak med opazovanji tudi daljši. Izven rastne dobe so opazovanja tedenska do mesečna. Zbiranje podatkov pridobljenih z opazovanji je različno - od dnevnega do letnega. Najbolj pogosto gre za mesečni termin. Informacijo o varieteti (kultivarju) vključuje v svoje podatke 90 % držav. Najbolj pomembna in s tem tudi pogosta so opazovanja kmetijskih rastlin, sledijo jim gozdna drevesa in grmičevje, na tretjem mestu pa so sadna drevesa. Najmanjši pomen se pripisuje negojenim rastlinam. K opazovanim podatkom so pogosto dodane še specifične informacije povezane s kmetijskimi deli (npr. dodajanje hranil, čas žetve, gostota rastlin,...). Običajno (78 % obravnavanih držav) baze fenoloških podatkov vsebujejo tudi informacijo o pridelku ter ekstremnih dogodkih (76 %). Večina držav ima fenološke podatke, opazovane od

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leta 1980 dalje, shranjene na elektronskem mediju, 4 izmed obravnavanih držav pa imajo v elektronski obliki celotno bazo fenoloških podatkov. Sam način zapisa podatkov (kodiranje) pa se med državami močno razlikuje. Fenološki podatki se najbolj pogosto uporabljajo kot informacija (agrometeorološka poročila), sledi jim uporaba v raziskavah ter vrednotenje agroklimatskih razmer. Pomembno vlogo pa igrajo tudi pri modeliranju pridelka. Glavni uporabniki so tako raziskovalci ter kmetijski svetovalci. V splošnem lahko ugotovimo, da se metode opazovanja, strukture opazovalnih mrež, način zapisovanja ter uporaba podatkov med posameznimi državami močno razlikujejo. Zato je namen WMO RA VI. Regional Association vzpodbuditi in podpirati standardizacijo opazovanj ter formata zapisa fenoloških podatkov. Pomembno je tudi poiskati povezave med fenološkimi in meteorološkimi podatki ter s tem povečati praktično uporabnost fenoloških podatkov npr. z uporabo pri modeliranju pridelka ali pri mikroklimatski klasifikaciji.

Ključne besede: fenologija, baze podatkov, mreža fenoloških opazovanj

Our questionnaire resulted in replies from 28 countries and from one international centre (Joint Research Centre). The answers seems to represent the given region properly but unfortunately we got only limited information (one completed questionnaire) from the Scandinavian countries. The 28 replying countries mean 57% of the members RA VI. Regional Association. The replies were positive namely regular phenological observations or networks exist in the following 22 countries: Armenia, Austria, Croatia, Czech Republic, Estonia, France, Germany, Hungary, Ireland, Italy, Izrael, Latvia, Lithuania, Macedonia, Moldova, Romania, Russia, Slovakia, Slovenia, Spain, Swiss, Syrian Arabic Republic and in the EU (JRC). We received negative answers from the next 6 countries: Belgium, Bosnia and Hercegovina (it existed from 1951 to 1992 but due to the civil war, the phenological observations were ceased, recently the old data are used), Denmark, Luxembourg, Portugal (there are phenological observations although without an organised network) and United Kingdom. It means that there are phenological observations in the 79 % of the states, which ratio is favourable.

This ratio would probably be even higher, if one took into consideration other phenological networks like International Phenological Gardens (IPG), plant improvement companies, cultivar experiment agencies, geographical societies, universities, plant protection services, forestry maintainers etc. The phenological networks are maintained by national meteorological or hydrometeorological services in 18 countries, only 5 countries place was reported other owners. The 2 oldest networks were organised in the 1920's and the most main time new phenological networks were initiated in the 1940's and 1950's (6 and 6 country, respectively). There are some relatively new observation systems starting in the 1980's (3 country) (Figure 1).

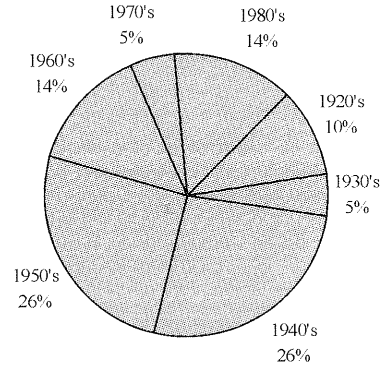

Figure 1: Date of establishment of phenological networks.

The density of networks shows great variability. The most dense phenological network works in Italy and in JRC (EU) (approximately 1 phenological station/ 100 km2) and the most sporadic is in France (approximately 1 station /100000 km2). The mean value of network density is 1 observation / 7400 km2. There exists no clear connection between the network density and the area of countries or the number of phenological stations.

The main part of networks are classified (74%) and there are not classified only in 6 cases (26 %). In spite of this fact, it seems that the phenological networks are not homogeneous considering the reported states. There are two main types of phenological networks: 1., agrometeorological, where mainly cultivated plants are observed and 2., (agro)climatological, where wild plants have emphasised importance. The distribution of phenological stations in given categories are showed on Figure 2.

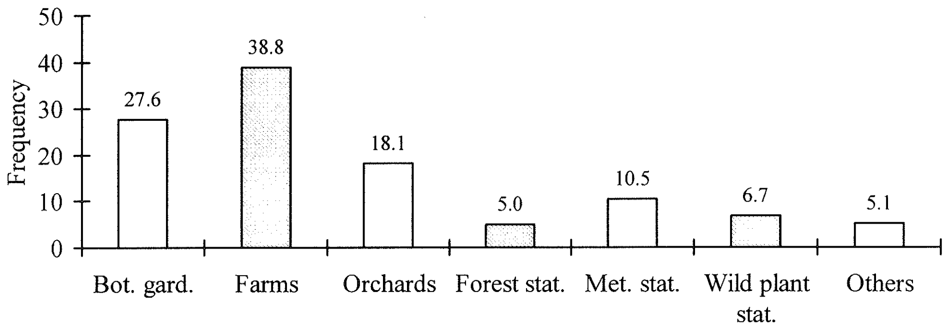

Figure 2: The frequency of phenological station types.

Most of observations are located at productive farms (39%) and orchards (18%) but also experimental stations (24 %) occur frequently. In two countries (Lithuania and Estonia) the phenological observations are connected to the normal meteorological measurements and stations. Other categories like forest and wild plant observing station, botanical garden, town and other places occur only infrequently albeit.

The qualification of observers is an undoubtedly important question, while it is one prominent component of data quality. In 21 countries, the observers are partly or fully professionals (specially qualified people), like agrometeorologists, agronomists, foresters etc. The ratio of professional observers is averaged at 61 %, which is considered high. This ratio changes large magnitude from the practically fully voluntary observers (0-1% professional observer) to fully professional (100 %) systems.

In three quarters of the countries observations are conducted during the whole year not only during the season. Naturally, observations are more frequent in the growing season. During the growing season, phenological observations are made in every one or 2 days (most commonly), but there exist some countries, where the frequency is 5 days, weekly or 10 days. Generally observations in orchards are less or equally frequent than concerning agricultural plants. Out of the season observations are made following frequency: only on a weekly, 10 daily or monthly basis.

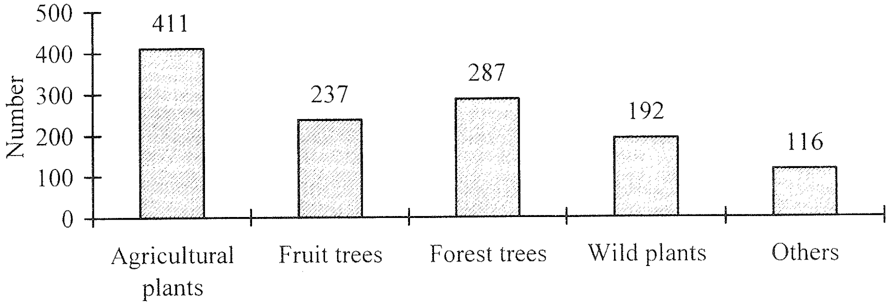

Figure 3: Number of observed species.

Frequency of data collection varies from daily to annually. The most common is the monthly data collection (Figure 3), but practically several (1, 2 or 3) parallel systems can exist simultaneously in one country. Sometimes these systems differ in the channels of data transmission. For annual data collection ordinary mail are appropriate in contrast to for quick (immediate) reporting stations, where the telephone, fax or similar methods are the most common. The data collecting channels are mostly via mail and telephone, but could also be telex, fax, telegraph or computer lines (intranet). The varieties (cultivar) information are incorporated into the data in 90 % of the total and left out only 10 % of the countries. The phenology of agricultural and vegetable plants has the greatest importance, the second highest value is the class of forest trees and bushes, the third one is the fruit trees and bushes, while wild plants have the lower importance. In few cases there are special phenological observations, like insect (bee), bird, plant diseases (Figure 3).

In order to increase the applicability and relevance extra information is also collected in 64 % of the countries. This include notes on agricultural practices, like nutrient supply, plant protection, time of sowing, plant density etc. Yield data are incorporated into the data sets in 78% of the countries, but it seems to be not relevant in the case of wild plants (less than 25%). Some information about the natural disasters are used in the 76 % of the phenological data banks.

In the last 30-40 years, the observation methods needed to be modified to adapt to changes in the structure of national meteorological services, development of social and technical environment of phenological observations. In two thirds of meteorological services, the phenological network has been altered since 1961. This number approximately equals to the number of existing networks in 1961, which means essentially that the all 'old' networks were more or less reorganised. In the last few years one third of the networks or methods were modified, but it seems that these changes have limited impact and in 75% of cases the results of the new observations remained comparable to the old ones. All countries keep their data on paper, resulting from the early start of phenological observations. In the last few years the use of computers become prevalent (75%). Most of countries have the phenological data on computers since 1980, but 4 countries have all the phenological data on computers as well.

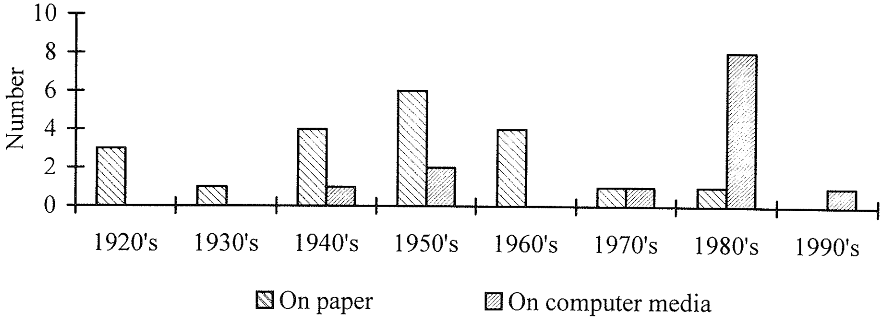

Figure 4: Data storage format.

The use of phenological coding is not common, only two thirds of the countries use any code. 10 countries reported the use of local (national specific) codes. Decimal scale is applied only in 6 countries therefore it cannot be considered common system. Other standard codes are used in 4 countries. The volume of stored data is the function of the number of observation places, observed plants, length of time series and the computer format of data storage. The smallest value (simple text format) is 1 MB, but in the case of extended networks and special data formats (Microsoft Excel, relational data base administrative programs) it could exceed 100 MB. The highest value (400 MB) is reported from Italy.

It is very important to identify the usage of phenological data (Figure 5). The main usage (37%) concerns agrometeorological reports, bulletins. The second greatest usage is research (24 %) and agroclimatic evaluation (22 %). It is not possible to neglect the importance of crop modelling (14 %), since the phenological development is one of the core parts of the crop-weather models. This fact also determines the distribution of data customers. The main users of phenological data are researchers (37 %) and farming advisors (30 %), but it is also used in a great extent in yield forecasting and yield estimation (18 %). Data are also used in other fields like environmental agencies (8 %), insurance companies (1 %), media (5 %), universities and education (2%) and allergology (0.5%).

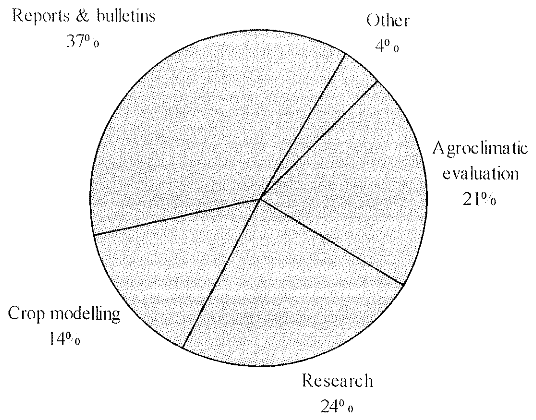

Figure 5: Type of usage of the phenological data.

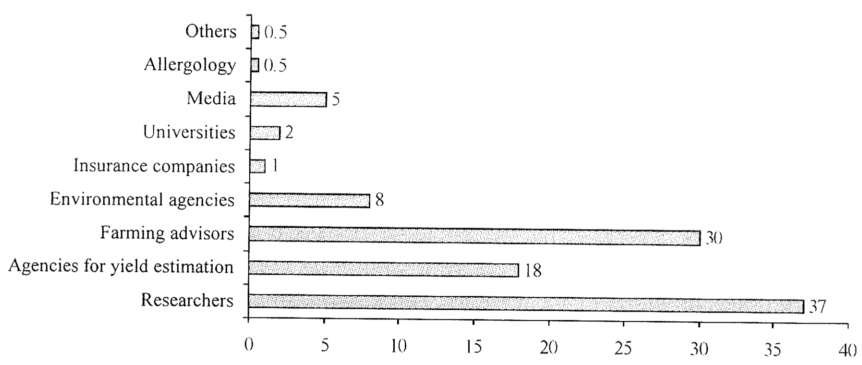

Figure 6: Distribution of users of phenological data.

In order to disseminate the data in operative use several media are applied (Figure 6). These include telephone (16%), bulletin, digital form (computer lines, internet, intranet, magnetic disk) and mailing (12 % respectively) and newspapers (10 %). Other possibilities are smaller, there are radio (8%), telex, fax, teletext (6%), television, telegraph, regional agrometeorological centres (4%).

GENERAL REMARKS AND RECOMMENDATIONS

Surprisingly high number of answers were received to our questionnaire. The great ratio of existing observations and networks shows the importance of the phenology. The main reason of this can be the connection between natural environment (agronomic practice, agricultural research, wild plant developing stage) and the agrometeorological or agroclimatological practice or research.

However, the several existing problems cannot be denied either. The observed plant or rarely animal species and the observed phenological phases change from country to country. The accuracy of the observed phenological phases and data varies in a wide rage. One of the main factor acting on the data quality is the skill of the observers and the handbook of they use. The data quality depend not only on the qualification of observers, but also on the observed phenological phases, e.g. it is easier to observe the first flower than the 50 % flowering. Some conference or expert meeting or handbooks could increase the accuracy reliability and comparability of measurements.

There is a lack of international co-operation, although some exception exist, e.g. the IPG and the Central European Initiative in Phenology. The phenological observations, the applied observation methods, the structure of networks, the coding systems and the practical usage of data are highly diverse. The WMO RA VI. Regional Association can take the initiative and assist the countries of the region to standardise observations and phenological data format at least in some extent. It is also imperative to find the connections between meteorological variables and different phenological stages, to increase the practical usage of phenological data, by giving examples from yield forecasting to the microclimatological classification. Organization and maintenance of phenological networks often raise special problems, sometimes it is similar to the normal meteorological networks. It would be useful to collect some experiences on this field.

LIFE CYCLE OF THE MAIZE IN FRIULI-VENEZIA GIULIA AND SLOVENIA

ŽIVLJENSKI CIKLUS KORUZE NA OBMOČJU REGIJE FURLANIJE -JULIJSKE KRAJINE IN SLOVENIJE

Andrea Cicogna[1] and Marco Gani[2]

POVZETEK

V primeru koruze je fenofaza cvetenja ter zrelosti korelirana z določeno efektivno vsoto temperatur zraka nad pragom 10 °C EV(10 °C). Na podlagi petnajstletnih podatkov 34 fenoloških opazovalnih postaj na območju Slovenije in italijanske regije Furlanije - Julijske krajine, podatkov o maksimalnih in minimalnih dnevnih temperaturah za isto obdobje ter geografskih podatkov (nadmorska višina) so bile izdelane karte povprečnih letnih EV(10 °C), povprečnih EV(10 °C) v rastni dobi, povprečnih doseženih EV(10 °C) do fenofaze cvetenja ter karta verjetnosti za dosego EV(10 °C), ki ustreza pojavu fenofaze cvetenja, do določenega dne v letu. Pri izdelavi kart je bila upoštevana tudi korelacija med EV(10 °C) v določenem obdobju v letu ter nadmorsko višino. Na podlagi kart lahko vidimo, da obstajajo precejšnje razlike v klimatoloških karakteristikah med Slovenijo in regijo Furlanija - Julijska krajina. Na območju Furlanije - Julijske krajine, kjer koruzo pridelujejo, so sezonske vrednosti EV(10 °C) med 1400 in 1900 °C ter padajo v smeri od obale proti Alpam. Slovenija pa predstavlja precej bolj nehomogeno območje. V bližini italijanske meje (Vipavska dolina in obala Istre) so razmere podobne kot na območju regije Furlanija - Julijska krajina. Na vzhodni strani Alp pa so vrednosti EV(10 °C) precej manjše, zato je možno gojiti le zgodnjo koruzo. Na območju Slovenije vrednosti EV(10 °C) naraščajo v smeri od Alp proti Panonski nižini. Za koruzo obstaja velika verjetnost vodnega stresa v avgustu. Zaradi tega bi bilo najbolj ugodno, če bi do cvetenja prišlo že pred koncem julija. V južnem delu regije Furlanije - Julijske krajine obstaja velika verjetnost za to, v severnem delu, pa je verjetnost precej manjša. Zaradi tega je na tem območju smiselno gojiti srednje pozno koruzo namesto pozne koruze, še posebej če ni vzpostavljen namakalni sistem. Glavni namen študije je bil predvsem uporaba grafičnega prikaza agroklimatskih indeksov ter vključevanje povezav med fenološkimi ter geografskimi podatki za natančnejšo izdelavo fenoloških kart.

Ključne besede: fenologija, Italija, Slovenija, cvetenje koruze, vsota efektivnih temperatur, fenološke karte

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1 PHENOLOGICAL ACTIVITIES IN FRIULI-VENEZIA GIULIA

At the moment, in the region Friuli-Venezia Giulia, a phenological network doesn't exist. A first attempt was made in 1990, by ERSA (Regional Organization for Development of Agriculture), to study the cultivated arboreal and herbaceous crops, at the beginning of agro-meteorological activities. The network was closed in 1996. At the beginning of 1998 a phenological garden was founded in the town of Tarcento, in collaboration with the University of Udine.

2 CLIMATOLOGICAL APPLICATIONS

In this article we shall not describe real phenological activities but will describe an application of a phenological index in the Republic of Slovenia and in the region of Friuli-Venezia Giulia. In 1995, according to the decisions of the Italo-Slovenian Permanent Mixed Commission for the common defense against hail, a collaboration has been started between ERSA (through the Centre for Agrometeorological Services, CSA) and the Slovenian Hidrometeoroloski Zavod (HMZ, Hydrometeorological Institute) to conduct studies in the agrometeorological field. The first activity was to stress how the differences in climate between the two regions influences the development of the crops, with the goal of evaluating the most adapted varieties to be cultivated in the different habitats. This study, just finished, has concerned maize and sunflower but, in this report, we are going to describe only the results obtained on maize.

3 METHODOLOGY ADOPTED

With the same environmental conditions (absence of or similar hydrothermal stresses), if the seeding or the emerging of the crop is contemporary in two different places, in the warmest place the crops will reach a fixed phase of development (phenological phase) first. If we know the relationship between temperature and phenological phase and if we have a climatological database for a whole region, it's possible to trace on a map, the climatological average times or the days of delay for a fixed phenological phase; otherwise it's possible to show the probability of not reaching physiological maturity of the crop. We know that temperature is one of the principal variables which influence development of crops. There are many methods of calculating and accumulating temperature or thermal units for maize. In this study we used the method of Growing Degree Units (GDU):

$$GDU = [(Tmax + Tmin)/2] - 10$$

where Tmax = daily maximum temperature, Tmin = daily minimum temperature and 10 is the base temperature for growth. In maize the flowering and the maturity is correlated with the reaching of some fixed accumulated GDU values as shown, for example, in table 1 for each class of maturity. Using the values of table 1 we create same maps for the following variables:

- GDU yearly mean accumulation;
- GDU mean accumulation in the growing period;
- GDU accumulation in the emerging-flowering stage;
- Probability of reaching the values of GDU corresponding to the flowering and physiological maturity, within a particular date.

We used almost 15 years of data from 34 meteorological stations (Figure 1) located in the two regions. At the beginning, to draw the maps, we looked for the relation between elevation of the place and the variable GDU or the probability. With this relationship we computed the probability for every pixel on the maps. On the maps of the spatial distribution of GDU we considered also the residuals of the regression between elevation and mean GDU at each station. These maps take into account the general trend of GDU, which decrease with altitude, and the local effects due to the micro-climatic conditions.

4 RESULTS

As an example, we report two maps. In Figure 2 is drawn the mean seasonal GDU (period May-October). You can see that the two regions have different climatological characteristics. In the area where maize is cultivated in Friuli-Venezia Giulia, GDU is between 1400 and 1900 and decreases from the coast to the Alps. In these conditions it's possible to grow medium-late maturing maize. Slovenia presents a less homogeneous situation. Near the Italian border (the Vipava valley and the Istrian coast) we have a situation similar to the one in Friuli. On the East side of the Alps, GDU is lesser and in these conditions it's possible to grow only early maize. Moreover, GDU grows from the Alps to the Hungarian plane. For maize, the probability of having hydrological stress in August is very high. For this reason maize flowering should occur before the end of July. In the lower plane of Friuli there is a high probability of this condition (Figure 3); in the high plane the probability is low. For this reason, in Friuli-Venezia Giulia it's better to cultivate medium maturing maize rather than late maturing, especially if there is no irrigation water.

5 CONCLUSIONS

From these studies emerges a large bio-climatic discontinuity between Friuli-Venezia Giulia and Slovenia on the divide of the Giulian Alps. On the East side of the Alps, maize has enough GDU only for the early classes to mature; on the West side the amount of GDU is greater and is sufficient for all the phenological phases, but to avoid water stresses, especially during flowering, it is better to cultivate medium maturing maize (e.g. FAO 500). This study is an attempt to represent in a graphical format the agroclimatic indexes, using a method that allows a global view of the territory. This method can be used, as well, to represent climatological and biological parameters. For this reason it should be important to find, in the area of interest, the relationships between phenological development and geographical data (e.g. altitude). To have other information, or a paper with a detailed description of the study, contact the technicians of CSA or HMZ.

Table 1: Growing Degree Units (GDU) to reach flowering and physiological maturity in different FAO classes for maize.

Class (FAO)	Growing Degree Units (GDU)	
	Flowering	Physiological maturity
100	620	1250
200	680	1300
300-400	730	1350
500	780	1400
600	820	1450
700	870	1500
800	920	1600

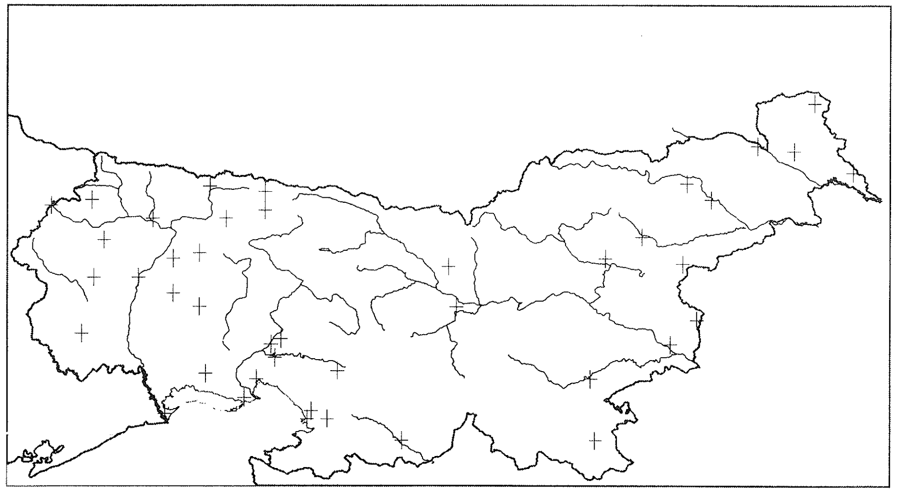

Figure 1: The 34 meteorological stations in Friuli-Venezia Giulia and Slovenia.

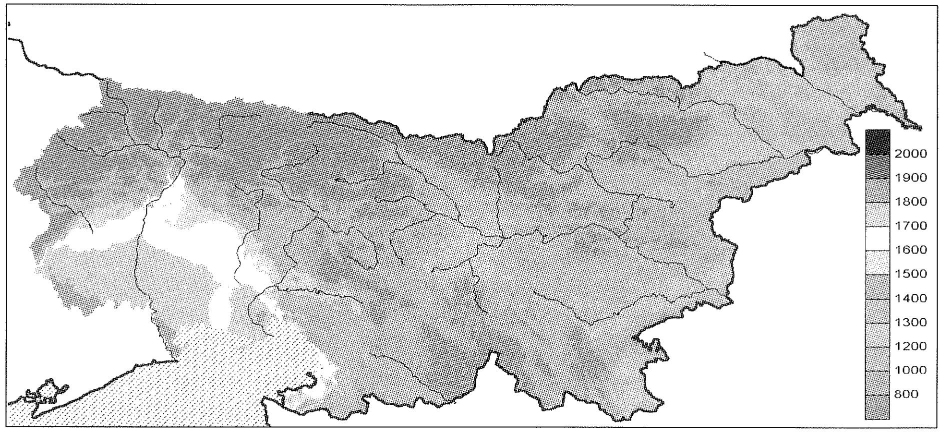

Figure 2: Accumulation of GDU above 10 °C in the period 1-May/31-October in Friuli-Venezia Giulia and Slovenia.

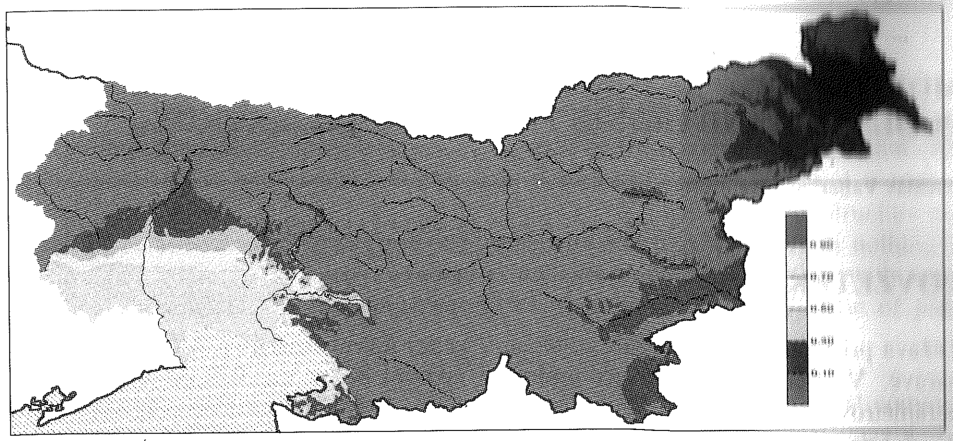

Figure 3: Probability to reach 850 GDU in the period 1-May/31-July in Friuli-Venezia Giulia and Slovenia.

MONITORING OF THE SEASONAL PROGRESS OF VEGETATION BY THE NORMALISED PHENOLOGICAL DATA

MONITORING SEZONSKE PRIRASTI VEGETACIJE NA PODLAGI STANDARDNIH FENOLOŠKIH PODATKOV

Jaroslav Valter[1] and Ivan Kott[1]

POVZETEK

Težava pri fenoloških podatkih je, da so v veliki meri nemerljivi in tako kvalitativne narave. V znanosti in tudi pri praktični uporabi se za razliko od meteoroloških parametrov, kjer zapisujemo vrednosti parametra ob določenem času, zapisuje čas, ko do določenega pojava pride - kvantificiranje fenoloških podatkov. Pri kartiranju fenoloških podatkov tako na določenem območju prikazujemo čas kot parameter, ko je bila dosežena obravnavana fenofaza rastline. V članku je obravnavan nov pristop, pri katerem bi analogno meteorološkim parametrom, tudi pri kartiranju fenoloških parametrov nanašali stopnjo razvoja vegetacije ob določenem času. Pri tem naletimo na problem, kako na nekem območju spremljati fenološki razvoj vegetacije, ki vključuje različne rastlinske vrste in kako je fenološki razvoj posameznih vrst med njimi povezan (npr. celotni travnik, gozd,...). Raziskava je na podlagi obravnavanja 6 letnih podatkov na 43 lokacijah (429 fenoloških fenofaz, 45 rastlinskih vrst - 16 dreves, 16 grmov, 21 zelišč ter enega travnika kot celote) pokazala, da vzporednost med fenološkim razvojem posameznih rastlinskih vrst ni idealna, je pa še vedno signifikantna. Osnova novega pristopa je letni fenološki koledar, ki predstavlja idealiziran časovni potek razvoja vegetacije na določenem območju oziroma v določenem kraju. Slabost fenološkega koledarja je potreba po dolgoletnih podatkih za posamezne lokacije, ki pa v večini držav niso na voljo. Zaradi namena primerjave ERS podatkov s fenološkimi podatki, so bile obravnavane fenološke faze, ki so direktno povezane z gostoto klorofila na obravnavanem območju.

Začetek vegatacijske dobe je definiran kot povprečje šestih fenoloških faz: začetek cvetenja (10 %) pri navadni jelši in lapuhu ter pojav popkov (10 %) gorskega jesena, breze, macesna in leske. Konec vegetacijske dobe pa je definiran kot povprečje petih fenofaz: konec odpadanja listov (100 %) pri macesnu, kostanju, bukvi, navadni jelši ter sivi jelši. Na podlagi klasičnih fenoloških podatkov ter ocene začetka in konca rastne dobe, je bila izdelana nova metoda, ki kot izhodni parameter podaja parameter biološki čas. Biološki čas je parameter, ki predstavlja merilo za razvojno stopnjo obravnavane vegetacije tekom leta.

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Ključne besede: fenološki koledar, biološki čas, navadna jelša, lapuh, gorski jesen, breza, macesen, bukev, siva jelša

ABSTRACT

A very important disadvantage of phenology is that this type of information has qualitative nature - phenological stages and development itself represent a row of morphological or physiological events based prevailingly on change of structure and shape. Thus, phenological stage is typically a structural pattern where is nothing to measure nor count; it is purely qualitative and discontinuous function with some additional parameters - mainly time (terms of occurrence), locality, name of plant species (genotype).

Both in science and practice, use of phenological information has its most common principle in comparison with meteorological, physical or geographical quantitative variables that have the same or analogical parameters of time and /or space. What is compared in these cases, is not phenological stage itself but the parameters. It is substantial to know that pure phenological information plays here the role of qualitative constant (e.g. .,"beginning of flowering").

In phenology , conventional mapping usually means to depict an area (using space parameters) as a field of data on terms (time parameters) of certain phenological stage, which is the same („constant") for all points of the area. The new approach considered here is to refer to development using a quantified and generalised phenological variable that should have a shape of continuous function (i.e., it gives the unique value for every point of time axis). Then, we could obtain fields („charts") where various points have various values of such phenological function for the same moment („time constant"). More commonly defined, we could dispose of a tri-dimensional matrix involving time-space information about development.

From the syn-ecological (spatial) point of view, there exist another problem connected with the discussed qualitative character of phenological information : it is question how to watch development of some important syn-ecological or phyto-geographical units (e.g., main forest formations, meadows or generally „vegetation cover" of certain area). The question is extraordinarily serious in earth remote sensing applications and modern mapping techniques, where often these vegetation units and not individual plant species are used as studied objects.

The substance of this problem is, to what extent phenological phenomena work on parallel or analogical principles at various species in a vegetation unit ; in other words, whether main tendencies in development of a species are detectable on the other species (at least selectively and with some transformation). In a row of years, this parallelism or synergism is considered as not fully rigid, rather statistical function,

significance of which is to be tested. A special part of this heap of problems is, how reliable are these relations between wild plants and field crops; we notice here the term „phenological indicator“.

It was just the idea to apply phenological data on wild plants as the „ground truth“ for MERA/MARS project purposes, that directed us to formulate these questions. Here we felt it would be useful to test if ERS data, mainly NDVI, are in good correlation with plant development or not and, moreover, if an above mentioned hypothetical development describing function which we hope to find couldn't be connected with or built into a crop production model, such as WOFOST.

In Czech Republic, we have worked out a method that may contribute to solving of this problem. The data system we want to introduce now in a brief presentation, needs on preparatory level both operative and long-term phenological data on wild plants. The fundamental idea is based on phenological annual calendar for a certain site, which is a time row of averaged data about the occurrence of a sufficient amount of phenological phases that are distributed over the whole vegetation period from early spring to late autumn. We have found that the mentioned parallelism between species or their phases is not perfect but still significant , which has been proved by sequential tests (6 years, 43 localities, 429 phenological phases, 45 plant species - 16 trees, 8 shrubs, 21 herbs plus permanent meadow hay harvesting) .

Phenological calendars represent an idealised time plan of development of vegetation for given region or site and, practically, they were applied in a few cases in CR and probably in other countries, too.

A disadvantage of these calendars is connected with the high need of long-term data from the locality, which is a rare feature of databases in most countries. Nevertheless, a modernised approach to the „calendar“ method seems to be the best way to quantification and generalisation of phenological information. In the connection with our intention to compare somehow phenological and ERS data we oriented ourselves to such phenological phases which are narrowly connected with the density of the chlorophyll in the scanned country.

The start of the vegetation period is defined as averaged term of six phenological phases:
first flowers (10%) : common alder, coltsfoot and budding (10%): mountain ash, birch, larch, hazelnut.
The end of the vegetation period is defined as averaged term of five phenological phases:
end of fall of the leaves (100%): larch, hornbeam, beech, common alder and grey alder.

The complete information about involved species and phases is possible to obtain from authors during this meeting as a specimen of the input file. By means of gradual testing of a row of selected expressions that were partly found in literature, partly were formulated as our hypotheses, we finally found as the best the following formal procedure :

$$SN = (SF1 + SF2 + SF3 + SF4 + SF5 + SF6) /6 ; \qquad [1]$$
$$KN = (KF7 + KF8 + KF9 + KF10 + KF11) /5 ; \qquad [2]$$
$$BTF = (NF - SN) / (KN - SN) ; \qquad [3]$$
$$BTDN = (BTFa + BTFb \ldots + BTFi)/ i ; \qquad [4]$$
$$BTDA = (BTFa + BTFb \ldots + BTFi)/ i ; \qquad [5]$$

where

SN	ng-term start of vegetation period gained from phases F1 to F6 - see above;
SF1, SF2, …, SF6	long-term values of these „starting“ phases;
KN	long-term end of vegetation period gained from phases F7 to F11;
KF7,KF8,KF9,KF10,KF11	long-term values of these „finishing“ phases;
BTF	biological time corresponding to given phase (its permanent value);
NF	long-term value of the given phase;
BTDN	biological time corresponding to given day (its permanent value);
BTFa, BTFb, ..., BTFi	BTF - values of the phases long-term averages of which fall on the given day;
BTDA	actual value of the biological time for the given day;
BTFa, BTFb, ..., BTFi	BTF -values of the phases actual terms of which fall on the given day.

According to our conception ,the gained time row of the BTDN values create contents of the term „biological time“, briefly „biotime“. Practically , the most important is the fact, that comparison with analogical actual time row composed of BTDA values and representing actual year is easy possible. The obtained differences express quantitatively the acceleration or deceleration of the development of the vegetation during actual year.

Recently, the software enabling computation of the biotime was finished (KALEND_7) and a few years have been already worked out. Final results including ERS data are planned to be obtained during the next year.

PHENOLOGICAL DATA EXCHANGE OF CULTURAL PLANTS OF CENTRAL EUROPEAN COUNTRIES

IZMENJAVA FENOLOŠKIH PODATKOV ZA GOJENE RASTLINE MED DRŽAVAMI OSREDNJE EVROPE

Pavol Nejedlik[1]

POVZETEK

Na pobudo Madžarske meteorološke službe so se decembra 1995 med državami osrednje Evrope začeli pogovori o uporabi in koristnosti fenoloških podatkov v agrometeorologiji. Vodilo pogovorov je bilo povečati uporabnost fenoloških podatkov v operativne namene ter ustvariti bazo podatkov za izmenjavo ter regionalni prikaz izbranih kulturnih ter negojenih rastlin. Devet držav se je pridružilo omenjeni aktivnosti, med njimi tudi nekaj držav iz Balkana. Opaziti je bilo različne načine opazovanja, zapisovanja ter obdelave fenoloških podatkov med posameznimi sodelujočimi državami (Češka, Madžarska, Nemčija, Poljska, Slovaška, Slovenija). Nestandardiziranost fenoloških podatkov predstavlja največji problem v povezavi z mednarodno uporabo le-teh. Pri opazovanju gre v večini primerov za opisne in ne številske podatke, pri čemer je očitno pomanjkanje standardnih metod opazovanj razvojnih stopenj rastlin. Administrativne meje omejujejo koriščenje fenoloških podatkov na mednarodni ravni, poleg tega pa različni metodološki pristopi, vključno z zapisovanjem podatkov, omogočajo uporabo fenoloških podatkov samo med kompatibilnimi sistemi. Za vzpostavitev regionalnih baz fenoloških podatkov so bili predlagani naslednji kriteriji: 1) zadostno število reprezentativnih fenoloških postaj; 2) enotna izbira rastlin; ter 3) univerzalen zapis podatkov, ki bi služil morebitni izmenjavi. Poskusno je bil v namene izmenjave izbran enoten zapis za osnovne fenološke faze kulturnih rastlin glede na metodologijo, ki jo uporabljajo v posameznih državah. Za vegetacijsko obdobje 1995/1996 so bile za primerjavo izbrane sledeče kulturne rastline: ozimna pšenica, koruza, (oljna) repica in krompir ter njihove tipične fenofaze. Izbira postaj je bila prepuščena posameznim državam osrednje Evrope, katere območje je bilo definirano kot območje med zahodno mejo Nemčije ter vzhodno mejo Poljske, ter med Baltiškim in Jadranskim morjem. Skupno število opazovalnih postaj je bilo 255 (Češka - 78, Madžarska - 12, Nemčija - 20, Poljska - 30, Slovaška - 63, Slovenija - 52). Ker se podatki v posameznih državah zapisujejo v različni obliki, je bila izdelana univerzalna oblika zapisa fenoloških podatkov. Še vedno pa so se v povezavi z izmenljivostjo podatkov pojavljale številne težave, kot na primer neopazovanje nekaterih fenofaz, različni aspekti opazovanj (popolna

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zrelost/začetek zrelosti) ter različna časovna perioda opazovanj (2 do 10 dni). Zaradi tega sodelujoče države menijo, da je nesmiselno povečevati število obravnavanih rastlin in fenofaz, temveč tudi v prihodnje opazovati omenjene rastline in njihove fenofaze ter obstoječim podatkom tako pridružiti nove časovne nize. Poleg tega, naj bi bila v prihodnje večja teža na reprezentativnosti postaj ter interpretaciji podatkov in ne na številčnosti le-teh.

Ključne besede: fenologija, baze podatkov, izmenjava podatkov

Phenological observation form the necessary part of agrometeorological information system both in long-term evaluation and in operational practice. First systematic and regular observation on the country level of cultural crops and wild plants started in most of Central European Countries (CEC) in the middle of 19 th century. Though the region of CEC is relatively homogenous there is no uniform access to the phenological observation and the range of the observed plants also varies from country to country.

Following the initiative of Hungarian Meteorological Service the discussion of the CEC countries around the use and benefit of phenological data in agrometeorology started in December 1995 and continued for two times. The aim of this effort is to increase the usage of phenological data in operational use and to create a base for data exchange and possible regional evaluation of phenological manifestation of selected crops and wild plants. Nine countries, including some Balkan countries joined this activity. Different ways of observing, coding and processing phenological data in these countries were recognised.

The meteorological data for agrometeorological purposes are measured in each country quite extensively and usually recorded by using standard procedures. Phenological data are not so well defined and are not measured in any standardised manner. Observing phenological data many descriptive elements occur in the methodology and there is lack of references to standardised procedures for observing growth stages. While meteorological and climatic data are at a certain level suitable for international data exchange, the discuss has shown many obstacles in phenological data accessibility for exchange purposes. Firstly formal and administrative boundaries restrict the utilisation of phenological data at the international level, secondly different methodological accesses including coding enable to use the phenological data just in the compatible system of processing. Though the general access to the observation is very similar many detail differences require to find any common expression of observed data that would make the data comparable. Thus to create any regional database of phenological data following criteria were considered:

-sufficient number of representative phenological stations;
-uniform crop/fruit tree selection;
-any universal coding that could serve as a platform for data exchange.

For the exchange purpose decadic code (concept of BBCH scale) was adopted to be used for the definition of basic phenological phases of the crops with the respect to the methodology used in each country. Considering two first criteria following intersection of plant and phenological phases during the vegetation season 1995/1996 was selected to create a pattern of restricted regional database of cultural plants:

Field plants

	Crop plant selected			
phenological phase	winter wheat	maize	rape	potato
sowing/planting	x	x	x	x
emergence at 50 %	x	x	x	x
first flowers	-	-	x	x
beginning of heading	x	x	-	-
beginning of tasseling	-	x	-	-
canopy closure	-	-	-	x
full ripe	x	x	x	-
harvest	x	x	x	x

Fruit trees

	Fruit tree selected		
phenological phase	sweet cherry	red currant	potato
first leaves	-	x	x
first flowers	x	x	x

All the data were expressed in the term of Julian day that represents the occurrence of the defined phenological phase together with variety description as a notice. As the data are recorded and archived at various formats from country to country an uniform formular was created for the data collection in ASCI II code, Excel version respectively.

Station selection was individual according to the country and varied considerably as some stations provided data for all selected crops and trees while some of stations were represented just by one plant.

This way the data from 255 phenological stations from six countries were collected with following station distribution:

Czech Rep.	Germany	Hungary	Poland	Slovakia	Slovenia	Total
78	20	12	30	63	52	255

Thus the area of Central Europe was represented from the western border of Germany to the eastern border of Poland and from Baltic to Adriatic see with following co-ordinates of "marginal stations":

Station	Latitude	Longitude
BREDSTEDT	54° 37`	08° 58`
RIZANA	45° 33`	13° 51`
ZAMOSC	50° 42`	23° 15`
ESCHWEILER	50° 49`	06° 16`

Top altitude : KOPRIVNIK - 1000 m a.s.l.
Min. altitude : BREDSTEDT - 10 m a.s.l.

Despite of the fact that the above described activity arose as a result of previous discussion the sets of data at each particular plant were not covered enough by data and some detail discounts have occurred:
- the absence of the data of some phenological phases (full ripe, first leaves)
- different point of observation in some cases (full ripe/beginning of ripe)
- different time step of observation/interpretation (from 2 to 10 days).

Considering these incorrectness it looks profitable for the future to restrict the number of stations with the particular plant and to focus on the representativity of the station position and data interpretation.

Final data interpretation should give us a review of the phenological cycle of the selected plant within the region. For this purpose the conversion to a graphic system was done and all the data can be interpreted in the map form (see a pattern in APPENDIX).

Recognising the obstacles in the even restricted uniform phenological database the CEC participant countries suggested not to widen the existed number of plants and phenological phases entering such database, but to follow in this activity regularly adding the data sets of next season of vegetation 1996/97.

APPENDIX (maps of phenological phases of winter wheat within the CEC region in the season 1995/96)

1. **SOWING**
2. **BEGINNING OF HEADING TO HARVEST**
3. **HARVEST**

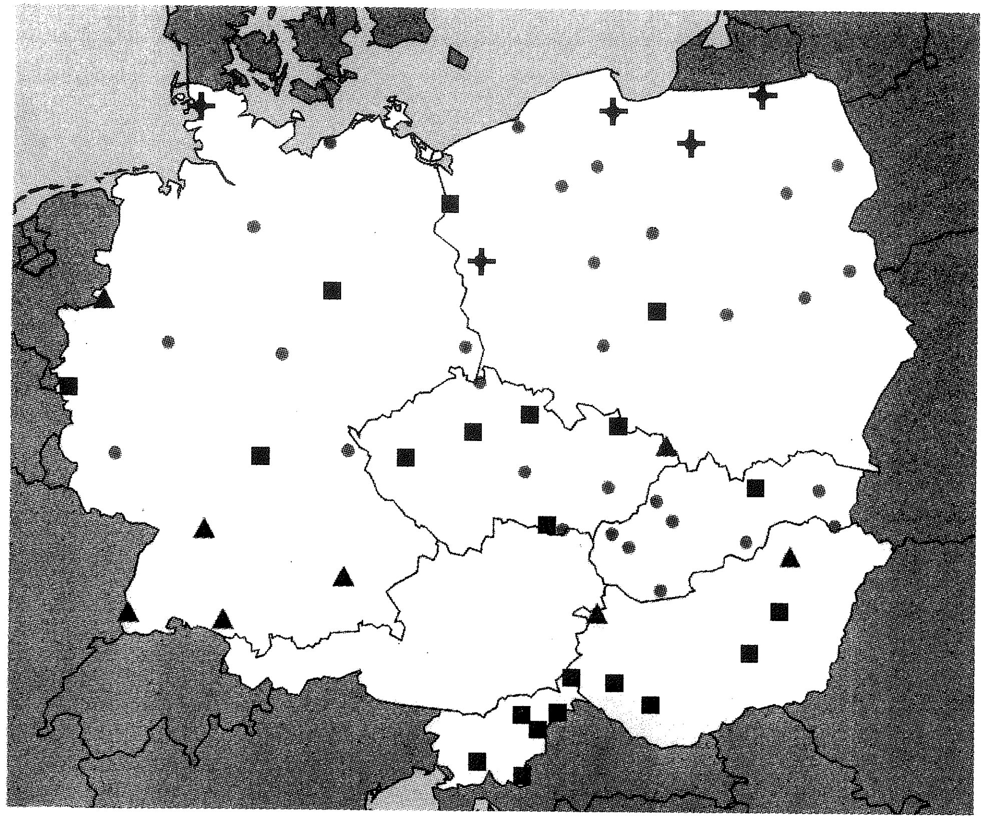

Figure 1: Project on phenology of CEC – phenophase *sowing of winter wheat* in the season 1995/96.

Legend:

▲	22.10.- 06.11.
■	07.10.-21.10.
●	22.09.-06.10.
✚	05.09.-21.09.

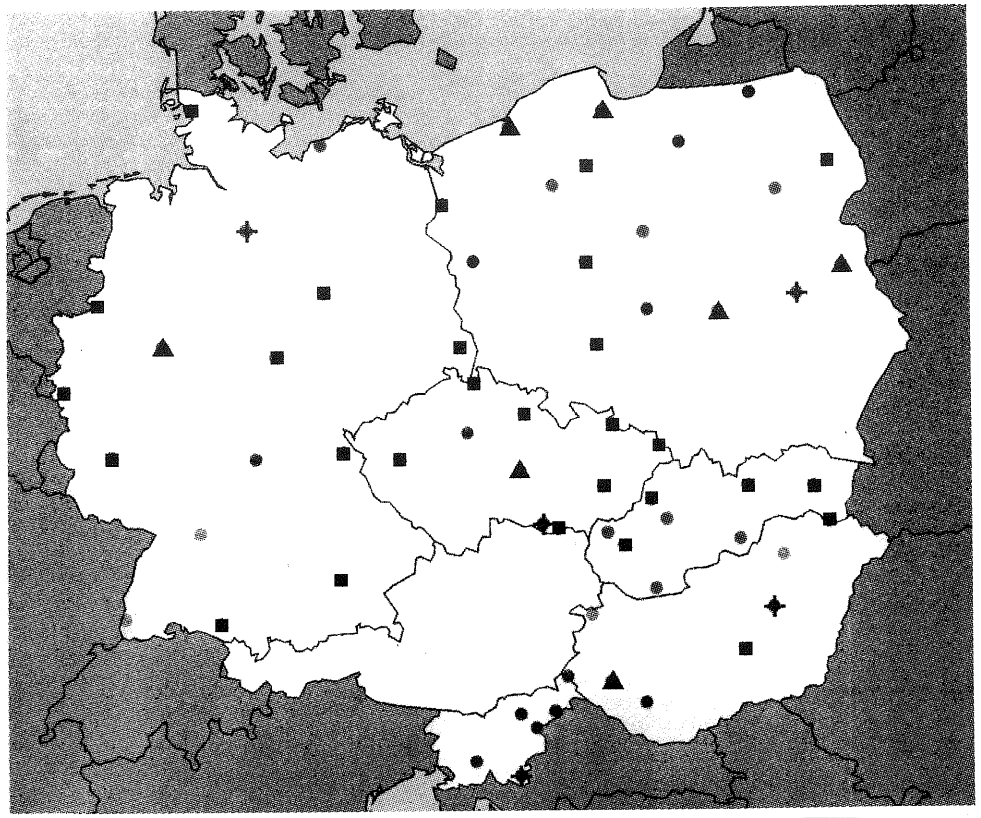

Figure 2: Project on phenology of CEC – phenointerval (in days) *beginning of heading to harvest of winter wheat* in the season 1995/96.

Legend:

▲	92 - 81
■	80 - 69
●	68 - 56
✚	55 - 48

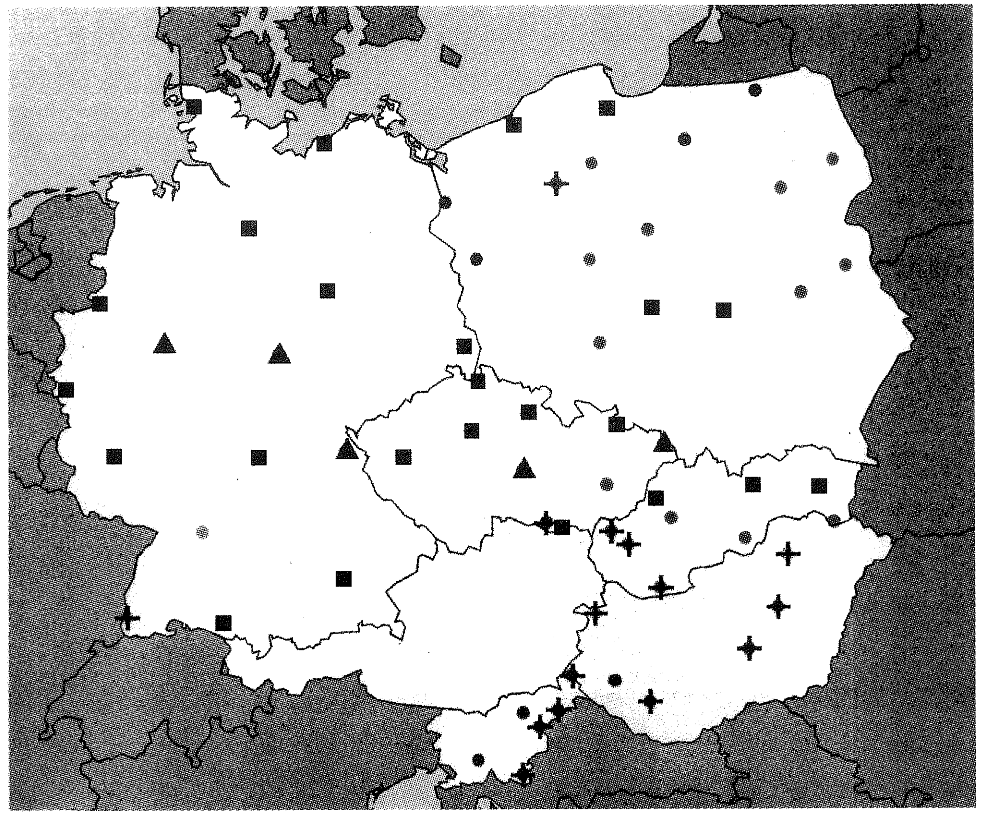

Figure 2: Project on phenology of CEC – phenophase *harvest of winter wheat* in the season 1995/96.

Legend:

▲	28.08.- 14.09.
■	10.08.-27.08.
●	26.07.-09.08.
✚	09.07.-25.07.

PHENOLOGICAL ARCHIVE SURVEY AND THE USAGE OF PHENOLOGICAL DATA IN SLOVENIA

FENOLOŠKI ARHIV IN UPORABA FENOLOŠKIH PODATKOV V SLOVENIJI

Ana Žust[1]

POVZETEK

V prispevku smo predstavili fenološki arhiv na Hidrometeorološkem zavodu Republike Slovenije. Fenološki arhiv zajema podatke o datumih pojava fenoloških faz opazovanih gojenih in negojenih vrst rastlin v obdobju od 1951 do 1998. Fenološki arhiv je do leta 1980 v klasični, od tega leta dalje pa v elektronski obliki. Elektronsko arhivirane datoteke so v ASCI zapisu, po letu 1995 pa z uvajanjem DBase datotek pripravljamo arhiv za delo z programom Oracle.

Trenutna fenološka mreža obsega 60 postaj. Opazujemo 38 negojenih in 23 gojenih rastlinskih vrst. Seznam opazovanih gojenih rastlinskih vrst dopolnjujejo še številne sorte. Podatki o enoletnih gojenih vrstah rastlin imajo krajše nize, v zgodnjem obdobju sorte niso definirane. Te podatke danes uporabljamo za agrometeorološke analize in ocene vpliva vremena na kmetijske rastline.

Podatki negojenih rastlinskih vrst so kvalitetnejši, zajemajo daljše nize, normalno porazdeljeni in zato primerni za statistično obdelavo. So dobro zastopani po celi Sloveniji. Problem predstavljajo manjkajoči podatki v izbranem nizu, čemur je potrebno prilagoditi postopek obdelave podatkov.

Fenološki podatki iz našega arhiva so bili osnova za mnoge raziskovalne in uporabne naloge. Trenutno v največji meri služijo raziskavam in uporabnim agrotehničnim namenom.

Ključne besede: fenološki podatki, fenološka opazovanja, fenološki arhiv

ABSTRACT

In the article we represent the Phenological archive of Hydrometeorological Institute of Slovenia. It comprises the data about the phenological phenomena of cultivated and uncultivated plants during the period 1951 to 1998. The data from 1951 to 1980 are

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deposited in classical archive, the data, following the year 1980, are kept in electronic archive. The data records are in ASCII forms after the year 1995, *DBase* data forms were a step to maintain the archive in Oracle.

The recent phenological networks consist of 60 phenological stations. The observations are carried on 38 species of not cultivated plants and on 23 species of cultivated plants. Observations on cultivated species are furthermore extended on various varieties. The data records of cultivated annual plants mainly comprise a few years' periods, in the early stage of phenological observances the varieties were not determinated. Those data are mostly used in agriculture surveys.

The data series of uncultivated plants are longer and prove a good quality. The phenological data of uncultivated plants adjust the normal distribution, therefore are suitable for statistical processing. They are mainly well distributed over the whole territory of Slovenia. The phenological data of our archive were data base for numerous investigations. The recent usage of phenological data is devoted to research and applicable agriculture purposes.

Key words: phenological data, phenological observation, phenological archive

1 INTRODUCTION

The phenological archive comprises the data of phenological phenomena of cultivated and uncultivated plants. Recently, the abundant bank of phenological data is unique in the country. The phenological data are devoted to various purposes: the documentation of annual phenological development of observed cultivated and uncultivated plants. In statistical processed forms manifest the phenological variation of plant growing upon the defined area. One of the aim of phenological data bank is devoted also to research purposes. The phenological data are particulary profitable when serve to agriculture purposes, when the growth development of productive agriculture plants is related to weather parameters. The phenological data of our archive were data base for numerous investigations.

2 ARCHIVE PROCESSING

Recently the phenological archive comprises the data of 206 phenological stations. In early fifties, phenological observations started on 30 phenological stations, later the number increased over 100 and ceased again to 60 stations in the last ten years. There are 51 stations with continuous data records even from the early beginning of observations, and another 39 stations with 30 year period of observations, but do not operate any more. Numerous other stations have shorter periods of data records.

The phenological observations are carried out on 38 not cultivated and 23 cultivated plant species (see APPENDIX and Figure 1). The list of cultivated plant species is extended by various varieties.

The observing area comprises the wide surroundings of the phenological station. Observations of forest trees, shrubs, fruit trees and vine are made permanently on one marked specimen. Herbaceous uncultivated plants are observed predominately on constantly location, while agricultural annual crops, especially those in rotation, are observed in the near surroundings.

In spite of unique form, there are no unique list of observations. On the Littoral, at forest locations and those over 800 meters above the sea level, the plant assortment distinguishes from the ordinary predominate stations.

There are 30 phenological phases, mostly easy to determinate even if the observer is unprofessional. Data are collected in the manner of monthly reports by mail. *On line* connection exists only for a limited number of phenological stations. Some stations give a note also about some field operations (hay making, sowing) and bees keeping. Those data are not archived and mostly serve in agriculture purposes.

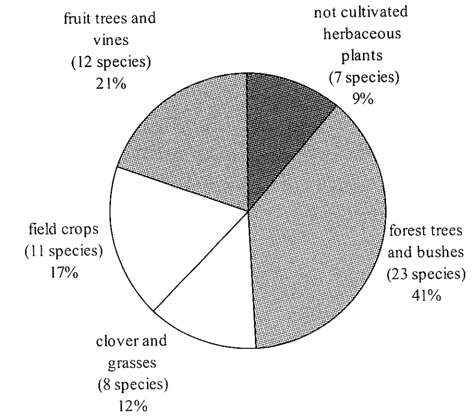

Figure 1: Share of plants in the assortment of phenological observations.

3 ARCHIVE

The sufficiently established archive makes phenological data - row or statistical processed - easy accessible. Establishing of archive was an extensive work with an aim to transfer classic form of archive to an electronic ones'. Electronic records of data comprise codes for phenological station, year of observation, phenological object, variety and phenological phase. Until 1995 the data records are in ASCI form, after the year 1995 in *DBase* data forms, in the future we intend to maintain the phenological archive in Oracle. Electronic archive comprises data following the year 1980, the data from the previous period are mostly in classical form (phenological books). Phenological data bank comprises 5MB of the storage space. The storage space is increasing by archiving the current phenological data.

Before the archiving the current phenolological data, the logical control eliminates the rough errors in registration of observation. Critical control is carried out next to process of the data using some simple graphical and statistical methods to examine the accuracy of the data. Questionable data are once again examined by analyzing the weather situation and eliminated if not reflect the real situation.

4 QUALITY OF THE DATA

Quality data is the most important characteristic of structured archive. Organizing the contents of the archive we confront with the impediments mostly the consequences of subjective and objective reasons. The subjective ones base upon subjective estimation of the phenological phase appearance and the objective ones originate from removal or cancellation of the phenological stations, or withering of plants in observation (frost, hail etc.).

In the early period of phenological observations until 1970, the annual cultivated plants were not determinated by varieties. Some phenological stages of annual cultivated plants have a considerable involvement of a man (sowing, planting, harvesting). In that reason the observations of annual cultivated agricultural plants are carried on predominantly in agricultural purposes.

On the contrary the data records of uncultivated and cultivated perennial plants prove good quality, the data records are longer (numerous stations more than 30 years), the data are mostly adjusted to the normal distribution. They are mainly well distributed over the whole territory of Slovenia.

5 GAPS

The weak point of phenological archive are gaps. The problem of gaps fairly arises in every statistical data processing. Consequently we can allow gaps and therefore risk bad results. Another way is to use proportionately shorter periods of data records or to fill the gaps with data from a cognate phenological station. For that kind of intervention a very good judgment of macro and micro location of observed phenological objects is needed. Any such interventions is reasonable only before the

statistical data processing. On basis of our phenological data some studies gave statistically confirmed relationships between the phenological phenomena and weather elements. The elevation is the another parameter which influences the vertical variability of climate elements influencing the plant development. Zrnec (1994) confirmed the close relationship between the phenological phenomena and the elevation and suggested the applicability of this relationship in filling gaps.

The relationships between the subsequent phenological phases of one variety or between phenological phase appearances of various plants or varieties gave firmly confirmation that the relation could be applicable also in filling gaps in the data records (Strajnar, 1997).

The figures 2 and 3 represent the graphical survey of the relationship between the flowering start for two varieties of vine (šipon and riesling blanc) in the vine growing region of Gornja Radgona in the north east of Slovenia. Figure 2 represents the regression line between flowering start of two vine varieties. Figure 3 represents the comparison of the data recorded in the period 1961 - 1990 compared to the serie of data quantified by the regression analysis.

Table 1: Regression relationship of blossoming start for various cultivars of vine and apples.

plant	plant	period	regression	R^2	region
Sauvignon (S)	Riesling Blanc (RB)	1961 - 1990	$Y = 0.8617 * RB + 21.976$	0.82	Slap pri Vipavi
Šipon (Š)	Riesling Blanc (RB)	1961 - 1990	$Y = 0,8761 * RB + 18.866$	0.75	Gornja Radgona
apple cv. Jonathan (J)	apple cv. Bobovec (B)	1961 - 1990	$Y = 0.7394 * B + 28.663$	0.70	Slovenske Konjice

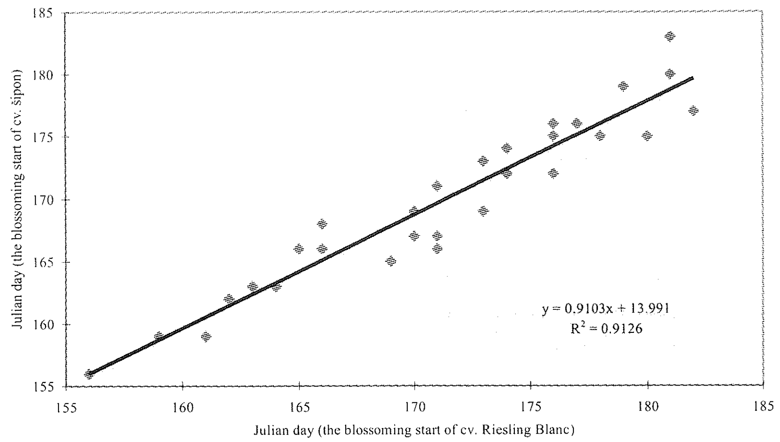

Figure 2: Regression line of the day of blossoming start of vine varieties laški Riesling and šipon in vine growing area of Gornja Radgona (period of reference: 1961 - 1990).

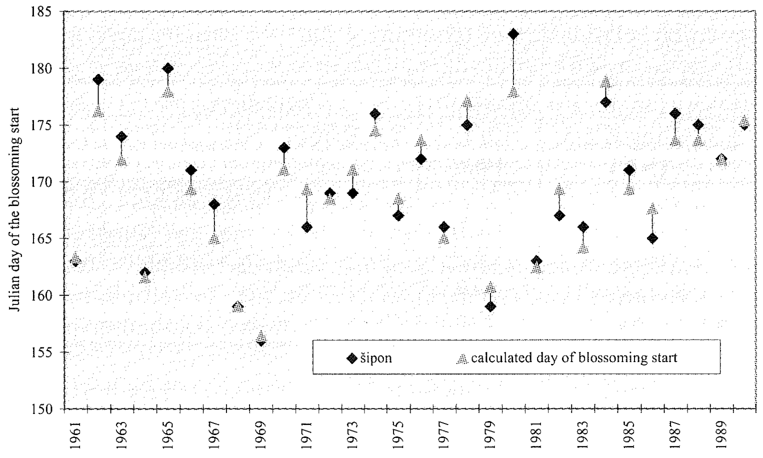

Figure 3: Blossoming start of vine cv. šipon (in Julian days) compared to the serie of data quantified by the regression relationship in the vine growing area of Gornja Radgona (reference of period: 1961 - 1990).

Firmly relationship was confirmed also between the beginning of flowering for two varieties of apple cv. Bobovec - an old and well distributed variety - is very related to cv. Jonathan in the fruit growing area of Slovenske Konjice in north east of Slovenia. The results are presented in Table 1.

6 THE RECENT USAGE OF PHENOLOGICAL ARCHIVE IN SLOVENIA

- documentation of annual phenological development of the observed plants on the territory of Slovenia, comparison to the average and extreme values with the purpose of agrometeorological analysis which are published in public media;
- testing of models where the phenological data records serve as the main or among the others input parameters;
- studying of climate influence on plant development resulting in trends of phenological phenomena;
- evaluation of agricultural area suitable for plant production with special temperature properties
- phenological maps prepared on the basis of methods of spatial interpolation and distribution of phenological data (allergenic plants)
- evaluation of crop coefficients applied in irrigation forecast models, indispensable for Slovene irrigation forecast model IRRFIB-2 elaborated at HMI. Adopted coefficients are based on phenological phases observed in different climate regions of Slovenia during the last 15 years.

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Arhiv HMZ.

APPENDIX

1 LIST OF PHENOLOGICAL OBJECTS

1.1 NOT CULTIVATED HERBACEOUS PLANTS

SNOWDROP *(Galanthus nivalis L.)*
COLTSFOOT *(Tussilago farfara L.)*
SAFFRON *(Crocus napolitanus Mord.& Loisel.)*
DANDELION *(Taraxacum officinale F. Weber & Wiggers)*
WHITE OX EYE DAISY *(Leucanthemum ircutianum Turcz. Dc.)*
AMBROSIA *(Ambrosia artemisiifolia L.)*
AUTUMN CROCUS *(Colchicum avtumnale L.)*

1.2 FOREST TREES AND BUSHES

HORSE CHESTNUT *(Aesculus hippocastanum L.)*
ROBINIA *(Robinia pseudacacia L.)*
LIME-TREE *(Tilia platyphyllos Scop.)*
SMALL-LEAVED-LIME *(Tilia cordata Mill.)*
BLACK POPLAR *(Populus nigra L.)*
ASH-TREE *(Fraxinus excelsior L.)*
OAK *(Quercus sp.)*
BIRCH-TREE *(Betula pendula Roth.)*
ALDER-TREE *(Alnus glutinosa (L.) Gaertn.)*
TREMBLING POPLAR *(Populus tremula L.)*
BEECH-TREE *(Fagus sylvatica L.)*
WILLOW *(Salix caprea L.)*
RED PINE *(Pinus sylvestris L.)*
BLACK PINE *(Pinus nigra Arnold)*
SPRUCE *(Picea abies (L.) Karsten)*
FIR-TREE *(Picea alba Mill.)*
LILAC *(Syringa vulgaris L.)*
COMMON ELDER BOURTREE *(Sambucus nigra L.)*
WILD-ROSE *(Rosa canina L.)*
HAWTHORN *(Crataegus monogyna Jacq.)*
BLACKTHORN *(Prunus spinosa L.)*
HAZEL-TREE *(Corylus avellana L.)*
CORNEL TREE *(Cornus mas L.)*

1.3 CLOVER AND GRASSES

BLACK CLOVER *(Trifolium pratense L.)*
LUCERNE *(Medicago sativa L.)*
BIRDSFOOT TREFOIL *(Lotus corniculatus L.)*
MEADOW FOXTAIL *(Alopecurus pratensis L.)*
ANNUAL MEADOW GRASS *(Poa pratensis L.)*
COCKSFOOT *(Dactylis glomerata L.)*
TALLOAT GRASS *(Arrhenatherum elatius (L.) P. Beauv. ex J.& C. Presl.)*
TIMOTHY *(Phleum pratense L.)*

1.4 FIELD CROPS

WHEAT *(Triticum aestivum L.)*
WINTER BARLEY *(Hordeum vulgare L.)*
WINTER RYE *(Secale cereale L.)*
SPRING BARLEY *(Hordeum sativum L)*
SPRING OATS *(Avena sativa L.)*
BUCKWHEAT *(Fagopyrum esculentum Moench)*
MAIZE *(Zea mays L.)*
POTATO *(Solanum tuberosum L.)*
SUGAR-BEET *(Beta vulgaris sahl.)*
SUNFLOWER *(Heliantus annuus L.)*
SOYA *(Glycine hispida Max.)*

1.5 FRUIT TREES

APPLE-TREE *(Pirus malus)*
PEAR-TREE *(Pirus communis)*
PLUM-TREE *(Prunus domestica L.)*
CHERRY-TREE *(Prunus avium L.)*
NUT-TREE *(Junglans regia L.)*
RED CURRANT *(Ribes rubrum L.)*
BLACK CURRANT *(Ribes nigrum L.)*
MAHALEB CHERRY-TREE *(Prunus cerasus)*
APRICOT-TREE *(Prunus armeniaca L.)*
PEACH-TREE *(Prunus persica)*
OLIVE-TREE *(Olea europaea (L.) Batch)*
VINES *(Vitis vinifera)*