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

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

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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.

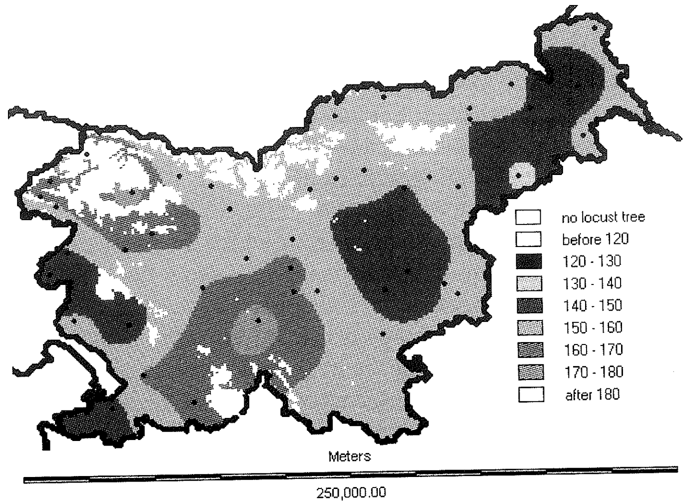

Figure 1: Flowering date (in Julian days) of locust tree (*Robinia pseudoacacia L.*) in year 1978 in Slovenia. Map was produced with ordinary kriging.

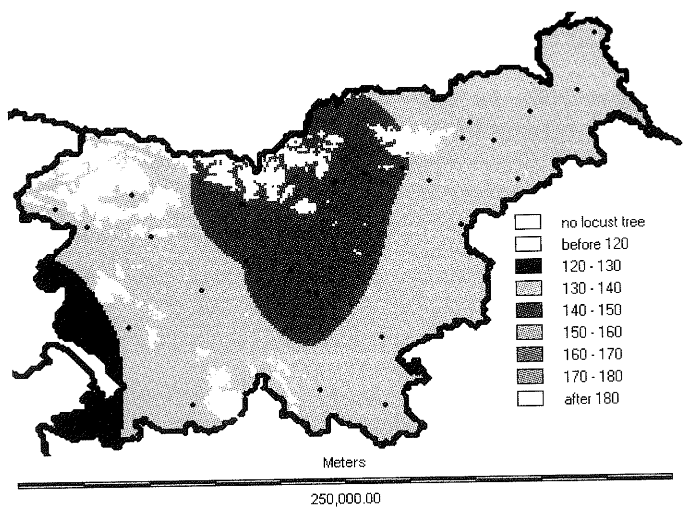

Figure 2: Flowering date (in Julian days) of locust tree (*Robinia pseudoacacia L.*) in year 1994 in Slovenia. Map was produced with ordinary kriging.

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.

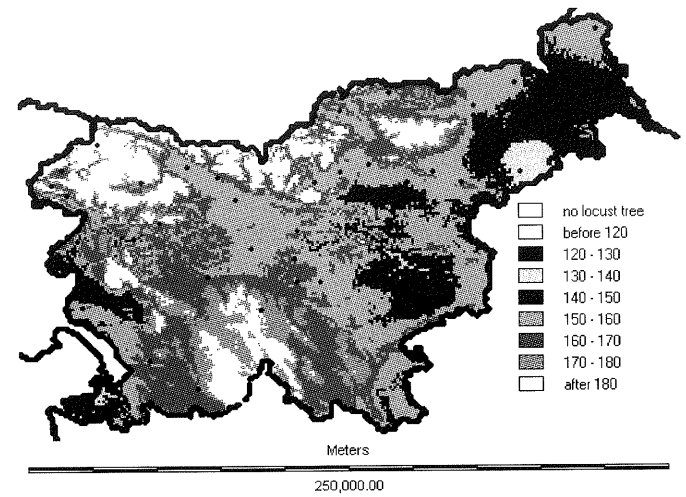

Figure 3: Flowering date (in Julian days) of locust tree (*Robinia pseudoacacia L.*) in year 1978 in Slovenia. Map was produced with kriging with external drift.

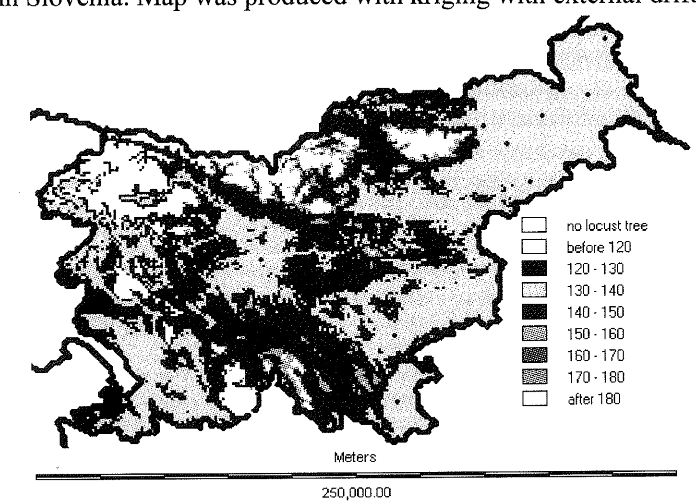

Figure 4: Flowering date (in Julian days) of locust tree (*Robinia pseudoacacia L.*) in year 1994 in Slovenia. Map was produced with kriging with external drift.

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.

REFERENCES

Isaaks H. I. and Srivastava R. M., 1989: *Introduction to Applied Geostatistics*, Oxford University Press, USA, 561 p.
Lieth H., 1974: *Phenology and Seasonality Modeling*, Springer–Verlag, USA, 444 p.
Wackernagel H., 1995: *Multivariate Geostatistics*, Springer–Verlag, Germany, 256 p.
Zar J. H., 1996: *Biostatistical analysis*, Prentice–Hall International IC, USA, 662 p.