Zoran Salopek, Master of Biotechnical Sciences

Zoran Salopek defended his master thesis titled *The Application of Remote Sensing in Assessing Soil Salinization in the Neretva River Valley* at the Faculty of Agriculture, University of Zagreb on September 12, 2008. The thesis was defended before the Commission, Prof. Dr. Davor Romić (mentor), Prof. Dr. Stjepan Husnjak, both from the Faculty of Agriculture and Prof. Dr. Renata Pernar from the Faculty of Forestry. It is extremely important to emphasize the guidance of Dr. Tomislav Hengl and all his help in forming hypotheses and data interpretation.

Zoran Salopek was born on August 3, 1980 in Zagreb, where he finished elementary and high school. After finishing high school in 1998, he enrolled the Faculty of Agriculture, University of Zagreb. He graduated under the mentorship of Prof. Dr. Dragutin Petošić in 2004. The same year he began to work as an assistant at the Department of Amelioration at the Faculty of Agriculture, where he still works.

The Application of Remote Sensing in Assessing Soil Salinization in the Neretva River Valley

During his postgraduate studies, he intensively participated in teaching. He also participated in numerous GIS seminars and courses for PhD students at the University of Hohenheim (Germany), the University of Nitra (Slovakia), the Joint Research Centre (JRC - Italy), the Croatian Ministry of Agriculture and GISDATA, a private firm. He is a member of the Croatian Soil Science Society.

The basic objective of this research was to determine the horizontal distribution of salt in the soil surface layer of the Neretva River valley. In addition, the goals were to apply advanced technology, such as remote sensing and GIS in discovering and prediction of salinized areas. Results of the research could help in reducing time-demanding and financially expensive field research.

Zoran Salopek's master thesis contains 71 pages of text, with 14 tables, 22 illustrations and 99 references. The work is systematized into following chapters:

1. Introduction
2. Overview of literature
3. Materials and methods
4. Natural conditions of the research area
5. Results
6. Discussion
7. Conclusions
8. References
9. Appendices

The *Introduction* describes the research location, as well as its spatial, hydrological and hydrogeological specifications. Soil salinization and its causes and consequences are notable issues. Understanding the complexity of the problem suggests the possibility of further progress of the above-mentioned process. Furthermore, the author highlights the extraordinary specificity and dynamism of this phenomena in nature and thus a lot of difficulties in the detection and prediction the aforementioned problems.

The author describes in detail the geographic, topographic, climatic, geological and hydrological features with the aim of better understanding of researched area in the chapter *Natural conditions of the research area*. Especially notable are pedological characteristics of areas with regard to the method of soil wetting as an important factor in the process of salinization.

The *Overview of literature* is systematized into two subsections. The first indicates the outspread of salinization problems in the world, Europe and Croatia. In addition, it describes in detail sources of salinity, conditions necessary for salt accumulation and soil salt tolerance limits. Furthermore, the author emphasizes papers dealing with different forms of soil salinity and resolutions of those problems. In addition, a lot of papers are cited, pointing out great possibilities of interpolation and mapping of salinized areas. At the same time, the author highlights how there is a whole range of possible approaches for solving the problem because of its complexity. The second subsection systematically lists difficulties and problems in the use of satellite imaging in assessing soil salinization. At the end, there is a list of

Zoran Salopek, magistar biotehničkih znanosti

Zoran Salopek obranio je 12. rujna 2008. na Agronomskom fakultetu Sveučilišta u Zagrebu magistarski rad *Primjena daljinskih istraživanja u procjeni zaslanjenosti tala doline rijeke Neretve*. Rad je obranjen pred povjerenstvom prof. dr. sc. Davor Romić (mentor), prof. dr. sc. Stjepan Husnjak, obojica s Agronomskog fakulteta i prof. dr. sc. Renata Pernar sa Šumarskog fakulteta. Izuzetno je važno napomenuti i komentorstvo dr. sc. Tomislava Hengla te svu njegovu pomoć na postavljanju hipoteze i interpretaciji podataka.

Zoran Salopek rođen je 3. kolovoza 1980. u Zagrebu, gdje je završio osnovnu i srednju školu. Nakon mature 1998. upisuje se na Agronomski fakultet Sveučilišta u Zagrebu. Diplomirao je 2004. pod mentorstvom prof. dr. sc. Dragutina Petošića. Iste godine započinje raditi kao znanstveni novak na Zavodu za melioracije na Agronomskom fakultetu, gdje radi i danas.

Primjena daljinskih istraživanja u procjeni zaslanjenosti tala doline rijeke Neretve

Tijekom poslijediplomskog studija intenzivno sudjeluje u nastavi. Sudjelovao je na brojnim GIS seminarima i tečajevima namijenjenima doktorantima i to na Sveučilištu u Hohenheimu (Njemačka), Sveučilištu u Nitri (Slovačka), Joint Research Centru - JRC (Italija) te onima u organizaciji Ministarstva poljoprivrede RH i firme GISDATA. Član je Hrvatskoga tloznanstvenog društva.

Temeljni cilj istraživanja u sklopu magistarskoga rada bio je utvrditi horizontalnu distribuciju soli u površinskom sloju tala doline rijeke Neretve. Osim toga, istražiti primjenu visokih tehnologija, poput daljinskih istraživanja i GIS-a u otkrivanju i predviđanju zaslanjenih područja. Rezultati istraživanja mogli bi smanjiti vremenski zahtjevna i financijski skupa terenska istraživanja.

Magistarski rad Zorana Salopeka sadrži 71 stranicu teksta u koji je uključeno 14 tablica, 22 slike, te 99 literaturna navoda. Rad je podijeljen u sljedeća poglavlja:

1. Uvod
2. Pregled literature
3. Materijal i metode
4. Prirodni uvjeti istraživanoga područja
5. Rezultati istraživanja
6. Rasprava
7. Zaključci
8. Literatura
9. Prilozi

U *Uvodu* opisuje se mjesto istraživanja te sve njegove prostorne, hidrološke i hidrogeološke specifičnosti. Posebno se ističe problematika zaslanjenosti te njezini uzroci i posljedice. Razumijevajući svu složenost toga problema ukazuje se na mogućnost daljnjega napredovanja spomenutog procesa. Nadalje, naglašava se izuzetna specifičnost i dinamičnost te pojave u prirodi te samim time i mnoštvo teškoća u otkrivanju i predviđanju navedenoga problema.

U poglavlju *Prirodni uvjeti istraživanoga područja* detaljno se opisuje geografske, topografske, klimatske te geološke i hidrogeološke značajke s ciljem što boljeg razumijevanja istraživanoga područja. Posebno se ističu i opisuju pedološke karakteristike područja s osvrtom na način vlaženja tla kao važnom čimbeniku u procesu zaslanjivanja.

Poglavlje *Pregled literature* autor je sistematizirao kroz dva potpoglavlja. U prvome ukazuje na raširenost problema zaslanjivanja u svijetu, Europi i u Hrvatskoj. Osim toga, detaljno opisuje izvore saliniteta, uvjete potrebne za akumulaciju soli te granice tolerancije soli u tlu. U nastavku ističe radove koji se bave različitim oblicima saliniteta tla te rješavanjem tih problema. Nadalje, citira mnoštvo radova ukazujući na veliku mogućnost interpoliranja i kartiranja zaslanjenih tala. Istodobno naglašava kako zbog kompleksnosti problema postoji cijeli niz mogućih pristupa njegova rješavanja. U drugom potpoglavlju sustavno se navode sve poteškoće i problemi u upotrebi satelitskih snimaka u procjeni zaslanjenosti tla. Na kraju se navodi niz radova koji u procjeni

series of papers using data obtained by means of remote sensing in assessing soil salinization.

All relevant factors related to the research are discussed in the chapter *Materials and methods*. The two-year research was carried out in the valley of the Neretva River. 152 soil samples were collected (0-30 cm.) during each of the years at the same locations for establishing horizontal distribution. Locations were selected with respect to the distance from the main channel and the distance from the sea. Sampled places are located in the area of Luke, Vidrice and Opuzen mouth that covers about 4000 hectares, which amounts to an average of 25.4 hectares per sample. Sampling time was selected with regard to adverse properties of salinized areas best recognized during summer months, when high temperatures, intense evapotranspiration and decreased precipitation cause ascendant movement of water and accumulation of salt in the surface layer of soil. The sampling method applied was 50% grid sampling, 700x700 m, 50% randomly. pH, EC, Na^+ and Cl^- were the variables researched. A map of salinized soils was obtained by means of the Ordinary Kriging interpolation method. Multiple linear regression was used to determine the relationship between the predictor and the dependent variable (EC).

The results of the *Research results* section begins with descriptive statistics of electroconductivity. In 2006, the results showed that the minimum and maximum value of EC is 0.37 dS/m, or 8.39 dS/m, while the average value amounted to 1.04 dS/m. In 2007, the smallest measured value was 0.42 dS/m, while the highest individual value even reached 11.86 dS/m, which prevents the cultivation of any cultural plant. The average value of EC was 1.70, which is a 61% increase from 2006. Expectedly, changes of EC were accompanied by changes in concentration of Na^+ and Cl^- ions. The next research results are those about geostatistical interpolation of EC. The accuracy of interpolation is proven by prediction errors. The author made only thematic maps for Na^+ and Cl^-, since it was not possible to make precise interpolation maps because of large prediction errors. The most important prediction error is RMS (root mean square), which represents the difference between the anticipated and measured values. In 2006, RMS for EC amounted to 0.9, and in 2007 to 1.19. For the purpose of verifying or dismissing the possibility of predicting soil salt variability using a model, the author applied the statistical method of multiple linear regression. EC values from 2006 were used as the dependent variable. As the model, i.e. independent variables that should explain the variability of salt in the soil, the author used a digital relief model, distances from the sea and channels and 14 bands of ASTER satellite imagery. The results showed that the digital model of relief (DMR), distance from the water and the sea, and ASTER bands 4, 6, 8, 9, 11 and 14 were the only significant predictors. The model explains 13% of variability of salt in the soil. The most important predictor was determined on the basis of specific coefficient *t*-values. Here, the ASTER band 9 (2.360-2.430 μm) was a statistically significant predictor at 0.001 level of error, and it can be claimed it is the best predictor of soil salinity within the model.

In the chapter *Discussion*, the author interprets achievements of his own research and associates them with results of numerous other authors. The high concentration of salt in some places is associated with penetration of sea water into soil and a high level of underground water in these areas. A 61% increase in the average concentration of salt in 2007 is interpreted with climate parameters, especially the lack of rainfall during summer months which is normally responsible for washing salt into deeper layers of soil. Furthermore, the poor quality of produced interpolation maps and a small percentage of variability of explained salts in the soil are discussed in detail. The author finds space for improvement in increasing the number of observations, using new predictors using hyperspectral images.

More information about the work and PDF version can be obtained via e-mail: salopek@agr.hr.

Stjepan Husnjak

zaslanjenosti tala služe podacima dobivenim daljinskim istraživanjima.

U poglavlju *Materijali i metode* sukladno cilju navode se svi relevantni čimbenici vezani za provedena istraživanja. Dvogodišnja istraživanja provedena su u dolini rijeke Neretve. U obje godine prikupljeno je po 152 površinska uzorka (0-30 cm) na istim lokacijama za horizontalnu distribuciju. Lokacije su odabrane s obzirom na udaljenost od glavnoga kanala i udaljenosti od mora. Uzorkovana mjesta nalaze se na području Luka, Vidrica i Opuzen ušća površine približno 4000 ha, što iznosi prosječno 25,4 ha po uzorku. Vrijeme uzorkovanja odabrano je s obzirom na to da se nepovoljna svojstva zaslanjenih tala najbolje uočavaju tijekom ljetnih mjeseci kada visoka temperatura, intenzivna evapotranspiracija, te smanjena količina oborina uvjetuju ascendentno kretanje vode te akumulaciju lakotopivih soli u površinskom sloju tla. Primijenjena metoda uzorkovanja bila je 50% mrežni način uzorkovanja, 700x700 m, 50% nasumično. Istraživane varijable su pH, EC, Na^+ i Cl^-. Karta zaslanjenosti dobivena je interpolacijom običnim krigiranjem (Ordinary Kriging). Višestrukom linearnom regresijom utvrđena je povezanost prediktora i zavisne varijable (EC).

Poglavlje *Rezultati istraživanja* započinje rezultatima elektrokonduktivnosti. U 2006. godini rezultati su pokazali da minimalna i maksimalna vrijednost EC iznosi 0,37 dS/m, odnosno 8,39 dS/m, dok je prosječna vrijednost iznosila 1,04 dS/m. U 2007. najmanja izmjerena vrijednost bila je 0,42 dS/m, dok je najviša pojedinačna vrijednost dosegnula čak 11,86 dS/m što onemogućuje uzgoj bilo koje kulturne biljke. Prosječna vrijednost EC iznosila je 1,70 što iznosi 61%-tno povećanje u odnosu na 2006. Očekivano, promjene elektrokonduktivnosti pratile su i promjene koncentracije natrijevih i kloridnih iona. Rezultati istraživanja nastavljaju se geostatističkom interpolacijom elektrokonduktivnosti. Točnosti interpolacije dokazane su predikcijskim pogreškama. Za Na^+ i Cl^- napravljene su samo tematske karte s obzirom na to da zbog prevelikih predikcijskih pogrešaka nije bilo moguće napraviti interpolacijske karte. Najvažnija predikcijska pogreška je RMS (root mean square) koji predstavlja razliku između predviđene i izmjerene vrijednosti. On u 2006. za EC iznosi 0,9, a u 2007. 1,19. U svrhu potvrđivanja ili odbacivanja mogućnosti predikcije varijabilnosti soli u tlu pomoću modela, autor je primijenio statističku metodu višestruke linearne regresije. Za zavisnu varijablu uzete su vrijednosti elektrokonduktivnosti iz 2006. Kao model, odnosno nezavisne varijable koje bi trebale objasniti varijabilnost soli u tlu, upotrijebljeni su digitalni model reljefa (DMR), udaljenost od mora i kanala te 14 pojaseva satelitske snimke ASTER. Rezultati su pokazali da su DMR, udaljenost od vode i mora te ASTER pojasevi 4, 6, 8, 9, 11 i 14 jedini značajniji prediktori. Model ujedno objašnjava 13% varijabilnosti soli u tlu. Na temelju specifičnih *t*-vrijednosti koeficijenta određen je najznačajniji prediktor. Tu se ASTER pojas 9 (2.360-2.430 μm) pokazao statistički signifikantnim prediktorom uz razinu vjerojatnosti 0,001 i za njega se može reći da je unutar modela najbolji prediktor saliniteta.

U poglavlju *Rasprava* autor postignuća vlastitih istraživanja tumači i povezuje s rezultatima mnogobrojnih drugih autora. Visoke koncentracije soli na pojedinim mjestima povezuje s prodorom morske vode u zaobalje i visokom razinom podzemnih voda na tim područjima. Povećanje prosječne koncentracije soli od 61% u 2007. tumači s pomoću klimatskih parametara, napose manjkom oborina u ljetnim mjesecima koje su zaslužne za ispiranje soli u dublje slojeve tla. Nadalje, detaljno se elaborira slaba kvaliteta izrađenih interpolacijskih karata i mali postotak objašnjene varijabilnosti soli u tlu. Prostor za poboljšanje pronalazi u povećanju broja opažanja, upotrebom novih prediktora i korištenju hiperspektralnih snimki.

Više informacija o radu i njegov zapis u PDF-u može se dobiti od autora putem e-pošte salopek@agr.hr.

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