SOIL VULNERABILITY ASSESSMENT FOR PESTICIDE LEACHING IN SAVINJA VALLEY

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ABSTRACT

A simple model of soil sensibility for pesticide leaching was developed using existing soil data (Soil Information System (SIS) of Slovenia with Digital soil map in scale 1:25000 (DPM25) as main data layer). The attribute data of soil organic matter content (SOM) and depth of soil systematic units (SSU) were used to calculate pesticide-holding capability (PHC). PHC integrate mentioned factors into relative numeric value that is added as a new data to the SSU attribute table. Validation of algorithm was done using PELMO model (one of FOCUS models) where – beside SOM and total soil depth – soil texture, bulk density, percentage of coarse material and thickness of soil horizons from representative soil profiles were used. SSU were classified into five categories according to the PHC attribute and graphically presented (with accordingly adjusted soil mapping units (SMU) of DPK25) as soil vulnerability map of tested area in Žalec and Celje community in Savinja valley.

Keywords: soil vulnerability, pesticide leaching, modelling, groundwater protection

OBČUTLJIVOSTI TAL ZA IZPIRANJE FITOFARMACEVSTSKIH SREDSTEV V SAVINJSKI DOLINI

IZVLEČEK

Izdelali smo model za opredelitev občutljivosti tal za izpiranje fitofarmacevtskih sredstev. Kriterije talnih lastnosti pomembnih za vezavo oziroma izpiranje FFS iz tal smo opredelili s točkami izračunanimi iz atributnih podatkov digitalne pedološke karte v merilu 1:25000 (DPK25). Pri razvoju algoritma smo uporabili delež organske snovi v tleh in podatek o povprečni globini tal. Podatke o teksturi tal, gostoti tal in deležu skeleta v tleh smo uporabili pri testiranju algoritma z modelom PELMO, ki je eden od uradnih modelov EU pri registraciji FFS (FOCUS). Pedosistematske enote (PSE) smo na osnovi izračunanih točk razvrstili v pet kategorij glede na tveganje izpiranja FFS iz tal. Glede na zastopanost PSE v kartografskih enotah DPK25 in smo izrisali karto ranljivosti za rabo FFS na območju občine Žalec in Celje v Savinjski dolini.

Ključne besede: ranljivost tal, izpiranje fitofarmacevtskih sredstev, modeliranje, zaščita podtalnice

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1 INTRODUCTION

Agrochemicals, particularly pesticides, have different fates after application. Most applied pesticides ultimately reach the soil, even when sprayed on plant surfaces. Some may volatilised or evaporated to the atmosphere; some could be transported by erosion or a surface runoff. Water can move pesticides into the soil, where they can be taken up by plants, broken down under biological degradation and by chemical reactions, or leached through the soil; they cause a potential threat to the groundwater [4]. Groundwater is often referred to as a source for drinking water and should be free of hazardous chemicals. Restrictions in use of pesticides and limitations in agricultural practice are measures taken to fulfil water quality criteria [2, 1]. Soil properties are one of the most important factors influencing the fate of pesticide in soil-groundwater system.

Many useful tools (models) exist for evaluation of pesticides leaching potential. Among several models four of them were included in pesticide registration process as a relevant tool to evaluate pesticide leaching potential on Tier 1 level. PELMO is one of them and it is appropriate when more general data of soil properties are available. Due to a great public concern regarding safe use of drinking water resources we tried to evaluate soil vulnerability for pesticide use. Evaluation was made on pilot area in our case at lower part of Savinja valley. In first step only soil properties were included and transformed to pesticide holding capability (PHC) classes and presented as a soil sensibility/vulnerability map for more precise implementation protection measures.

It is well known that soil organic matter and clay minerals are the most important soil components in pesticide retention after soil application. Furthermore, it is well established that the uptake of nonpolar organic compounds from aqueous solution is strongly correlated with soil organic matter content [3]. Normalisation of pesticide sorption by soil organic matter or soil organic carbon (K_{om} or K_{oc} coefficient) implies that organic matter is sole soil compound in pesticide retention. Such generalisation could be misleading, especially in sorption of more polar pesticides. Many other important factors are neglecting such as pH, CEC (cation exchange capacity), clay content and other soil mineral adsorption sites. In some cases each of these factors could play a crucial role in pesticide sorption. However, in general, organic matter content is the most important factor governing pesticide sorption. In our study this fact was considered as a most important factor in soil vulnerability assessment for pesticide leaching extent.

2 MATERIALS AND METHODS

The Digital Soil Map at scale 1:25000 (DSM25) is used as a basic reference database of Slovenian soils as a natural resource [7]. DSM25 has graphical (spatial) and attribute information. Graphic information is represented by soil mapping units (SMU) polygons with the properties described in attribute tables. Each SMU is composed of up to three different soil types soil systematic units (SSU). Soil profile (SP) data with site and horizons description and standard soil analyses represent additional point layer database with measured parameters. MS Access 2000 and MS SQL 2000 are used to maintain computer relational database with SMU units including SSU properties described in attribute tables (Table 1) and SP data. ESRI software (ArcGis 8.3) was used for GIS processing.

Layer data of land use information from MAFF (Ministry of Agriculture, Forestry and Food) were used for focusing GIS analysis only for agriculture land use. Outputs were tested on test area in Žalec and Celje community in Savinja valley where intensive agriculture is present above groundwater table that is an important source of drinking water.

Model FOCUS/PELMO 3.22 was used [6] to calculate potential risk of pesticide leaching through different representative soil profiles of pilot area [5]. Through indicative stage of modelling ponders for soil properties from DSM25 were determined. Ponders were included in algorithm for pesticide holding capability (PHC) calculation.
Pesticide with medium organic carbon partition coefficient (K_{OC}=200ml/g) as a measure of mobility and with medium to high half-life (HL_{50}=100 days) as a relative persistence was used on all soil types. Pesticide holding capability (PHC) was calculated for each SSU using results from PELMO model and attribute data (Table 1). Soil vulnerability maps were structured according to SMU composition and their spatial distribution (Fig. 1).

Table 1: Selected attribute data of soil systematic units (SSU) in digital soil map of Slovenia (DSM25)
Tabela 1: Izbrani atributni podatki pedosistematskih enot (PSE) digitalne pedološke karte Slovenije (DPK25)

Attribute class	DEPTH [cm]	TEXTURE (TEXSTUE CLASSES*)	ORGANIC MATTER [%]
1	Very shallow < 30	Coarse textured soil (heavy) (S, LS, SL)	Mineral soil <1
2	Shallow < 50	Coarse and medium textured soil (S, LS, SL, SCL, CL, L, SiL, Si)	Low OM 1–2
3	Moderately deep < 70	Medium textured soil (SCL, CL, L, SiL, Si)	Medium OM 2–4
4	Deep > 70	Medium and fine textured soil (SCL, CL, L, SiL, Si, SiCL, SiC, SC, C)	High OM 4–10
5		Fine textured soil (heavy) (SiCL, SiC, SC, C)	Very high OM >10
9	Wide range	Wide range	Wide range

* S – sand, LS – loamy sand, SL – sandy loam, L – loam, SiL – silt loam, Si – silt, SCL – sandy clay loam, CL – clay loam, SiCL – silty clay loam, SC – sandy clay, SiC – silty clay, C – clay

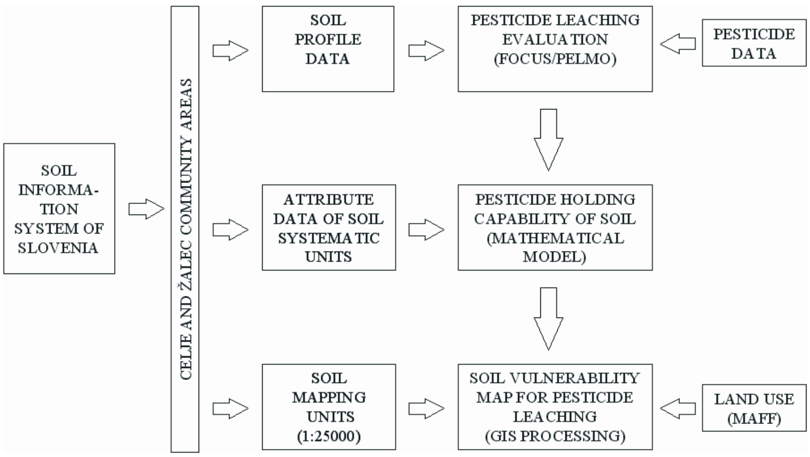

Figure 1: Simplified process of structuring soil vulnerability maps
Slika 1: Shema izdelave karte ranljivosti tal

3 RESULTS AND DISCUSISION

PHC was integrated into relative numeric value for each SSU at pilot area. The value of PHC ranging from 3 to 40, according to validation with PELMO model, five main categories of the interpretation scale from minimum (negligible) to very high concern for ground water contamination by pesticides were established. Each category was split into subclasses of sensibility with general recommendation of pesticide use (Table 2).

Table 2: Interpretation scale for the SSU according to calculated PHC expressed as soil sensibility for pesticide use or risk of pesticide leaching through soil profile

Tabela 2: Interpretacijski ključ za razvrstitev pedosistematskih enot (PSE) v kategorije tveganja izpiranja FFS iz tal glede na izračunano vrednost zadževanja pesticida v tleh

PHC value	Soil Sensibility		Risk of leaching pesticide from soil		
	Class	Characteristics	Level of concern	Category	Label in map
< 7	1	Inappropriate for pesticide use	Very high risk	I	Crosshatch
8-10	2	Inappropriate for pesticide use			
11-12	3	Inappropriate for pesticide use	High risk	II	Simple hatch
13-14	4	Sensitive soil for pesticide use			
15-17	5	Limited use of pesticide	Medium risk	III	Dot net
18-20	6	Limited use of pesticide			
21-25	7	Proper pesticide use is not problematic	Low risk	IV	Horizontal line
26-30	8	Proper pesticide use is not problematic			
33-35	9	Very high capability of pesticide adsorption	Negligible risk	V	Solid grey
36-40	10	Very high capability of pesticide adsorption			

Pilot area for testing soil vulnerability model for pesticide use was set in Žalec and Celje community. Testing area occupied 21200 ha of which 9018 ha is agricultural land (Table 3, Fig. 2).

Results of PHC assessment shows that high risk for pesticide use (Fig. 2) represents soil units developed on following soil classes according to FAO classification: Fluvisol, Regosol, Rendzinas and shallow forms of Cambisols. Main characteristics of soil units classified in first category regarding safe use of pesticides are low depth of soil profile and lower organic matter content. On the pilot area those units are mostly situated in the vicinity of Savinja river. Soil units of Rendzinas and Rankers could be found in hills on calcareous parent material (Pirešica, Liboje) and on Miocene sand and sandstone (Pirešica, Štore). In this category were classify 941 ha of agriculture land which represent 10% of all agriculture area (Table 3). In the second category where risk for pesticide leaching is still high, mostly cambisols (usually Eutric cambisol) with medium depth were classified. These units are represented in part of Savinja valley. However some other soil units of Dystric cambisol could be found on other parts of testing area. Area of this category represents 28% of agriculture area under investigation (Table 3).

Soils classified in third category represent medium risk for pesticides leaching. In this category many soil units of eutric and dystric cambisol with different parent material (marl, non sandy alluvial deposit, etc.) are included and also same soil units of Gleysols. It is the largest category where more than 5200 ha (58 %) of agriculture land were included (Table 3).

Only 1% of all area is covered by soil classified as a low risk for pesticide use. Deep soil units developed on alluvial deposit were classified in this category. On tested area no soil units were classified in category of negligible risk for pesticide leaching (Table 3).

Table 3: Area of different category of risk assessment for pesticide leaching
Tabela 3: Površina in delež različnih kategorij glede na ugotovljeno tveganje za izpiranje pesticidov

Category	Area (ha)	Area (%)
1 - Very high risk	941	10
2 - High risk	2524	28
3 - Medium risk	5224	58
4 - Low risk	56	1
5 - Negligible risk	-	-
Errror*	273	3
Total	9018	100

* Differences arise due to lower accuracy of urban zones in Slovenian soil map

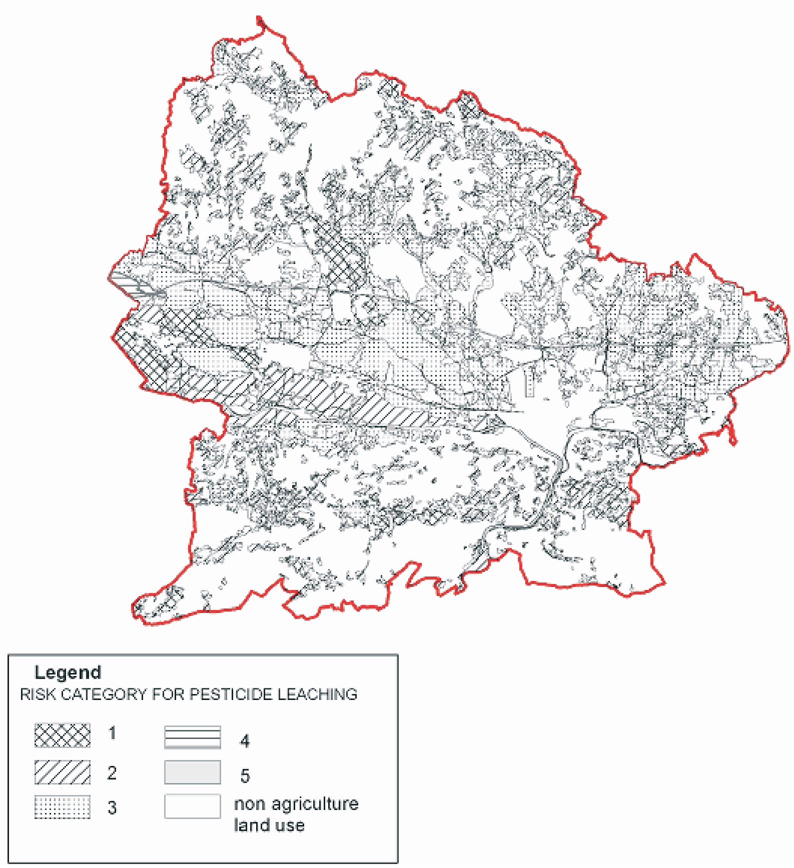

Figure 2: Soil vulnerability map for pesticide leaching
Slika 2: Karta ranljivosti tal zaradi izpiranja fitofarmacevtskih sredstev

4 CONCLUSIONS

Transformation of general (available) soil data into maps of soil vulnerability leaching using simple model with main attribute data for SSU has shown reasonable results on test area. More precise classification and description of soil vulnerability could be done using particular pesticide or pesticide groups according to their persistence and mobility data. Additional site characteristics and management practice in combination with climatic data could contribute to detail scale of thematic maps in the future.

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