NEW PRINCIPLE OF FARMLAND PRODUCTION POTENTIAL DETERMINATION

NOVÝ PRINCIP STANOVENÍ KRAJINNÉHO PRODUKČNÍHO POTENCIÁLU

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In this study a new method for determination and evaluation of the total production potential of farmland – TPP_F is presented. New pedological layers have been proposed from the viewpoint of the need to determine degradation parameters in the main soil representatives for subsequent limitation of production potential (delimitation parameter, blocking and homogenization parameter, hydromorphism, degradation of soil structure and constructions, danger of erosion, soil skeleton rate, infiltration capacity).

The theoretical basis for TPP_F calculation consists in the definition of production and environmental functions in agricultural landscape, the proposal of methodological procedure for the calculation of the above mentioned functions and the construction of calculation formulae, including determination of point span for particular numbers of SQEU (soil quality ecological unit) or MSU (main soil unit) code. Considering production function, correction coefficients for critical parameters have been newly proposed; in the calculation of environmental function, correction environmental parameters have been proposed.

The output of the proposed method consists in determination of so called spatial models consisting of the span determined for production function, and of the span for environmental functions of farmland (biomass production, filtration function, accumulation function, transformation function, buffer and transportation function, biological base, genetic pool, decontamination function, land as historical medium, raw materials source, space for human activities).

To verify the newly proposed method as well as the algorithm of the calculation itself some practical tests in the marginal area Šumava–Zdíkovsko have been launched.

Key words: environmental functions, total production potential, soil quality ecological unit

The study focuses on presenting a new method to solve the outlined problems in the Czech Republic, with the aim to change the current approach to natural resources conservation and with special attention paid to water resources protection V á c h a l and V á c h a l o v á [11].

The newly proposed method is based on the studies dealing with the production potential of soils. B l u m [1], D o r a n [2], K o z á k and N ě m e č e k [5], K a r l e n [4], L a r s e n with P i e r c e [6] and W a t k e r t i n [13], the classification of forest soils is described in their studies. A con-

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siderable change in knowledge on soil production potential is published in the monographs by H o r r i g a n [3] and P r e t z s c h [9]. We also considered the studies of Slovak authors B u j n o v s k ý and J u r á n i [12].

Soil quality is sometimes also interpreted as "the health of soil". It usually means a state when soil does not contain any pollutants or contaminants (from the point of view of food production, food chain or surface water and groundwater quality). This view is considered as rather narrow, incapable of expressing the capacity of soil to provide all its functions.

Many authors [2, 4, 10] define soil utilization and its quality as the ability to function within an ecosystem. Therefore it is possible to accept a very simple definition by Pierce and Larson [8] stating that soil quality represents its "suitability for general use". In other words soil quality is defined as a complex of physical, chemical and biological soil properties which provide for plant growth, regulate the cycles of nutrients and water as well as the flows of energy in the environment and influence both the inputs of various substances into the food chains and their leakage in the groundwater L a r s o n and P i e r c e [6].

MATERIAL AND METHODS

Bohemian Forest area belongs to other regions in Central Europe that have not been dramatically affected by human industry activities yet. This model area is located on Prachatice–Vimperk region in Bohemian Forest protected landscape area boundary, where autochthonous forest stands have been preserved (e.g. climax spruce stands, acidophilic beech woods, peat bogs). Local climate is typical for sub-mountain region, affected by rugged topography and high forest coverage. Annual mean rainfalls in a ten-year period reach up to 830 mm. Annual mean temperature is 5.9°C, average January temperature is –3.8°C, average June temperature is 13.5°C. Average relative humidity is 78 %, prevailing wind direction is northern. Geologically this area belongs to Bohemian Forest moldanubicum.

According to regional scale, model area includes mountain Bohemian Forest territory and less favourable Bohemia Forest areas, mountain type Montane – 1, Montane – 2, possibly categories Grain-growing region – 2 and Grain-growing region – 3. Into Bohemian Forest upland there are included areas with altitude over 800 m, where arable land has been converted into grassland. In these areas priority consists in increased landscape protection, especially in water resources locations and agricultural exploitation of such areas will be reduced to landscape maintenance.

According to local scale, model area is located in Zdíkov territory. Within the last 20 years marked changes in landscape structure have occurred here, which can be considered as typical for this region.

RESULTS

Decision – making algorithm of zonation formula

Determination is based on assumption that the total production potential of agricultural soils (TPP_{AS}) is calculated as the sum of production functions and non-production functions, whereas TTP_{AS} is all the time equal to the value of 100 % (maximum possible value ranges between 0–100 %) (fig. 1).

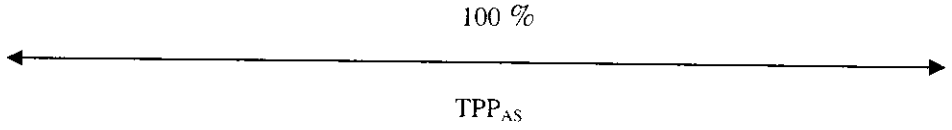
T a b l e 1

Structural changes in Zdíkov territory
Strukturální změny na území Zdíkov

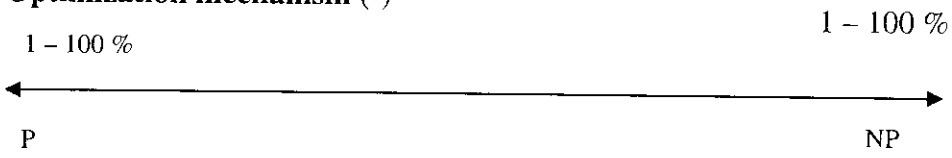
Plantation type (1)	1989		2004	
	area (6) (ha)	%	area (ha)	%
arable land (2)	319	49,7	108	17,3
permanent grassland (3)	268	41,8	489	78,4
special agricultural types (4)	54	8,5	45	4,3
sum (5)	641	100	642	100

(1) Typ osídlení, (2) orná půda, (3) trvalé pastviny, (4) speciální hospodářské typy, (5) součet, (6) výměra

a) Decision – making spectrum ([1])



b) Optimization mechanism ([2])



c) Basic zoning formula (limiting) ([3])

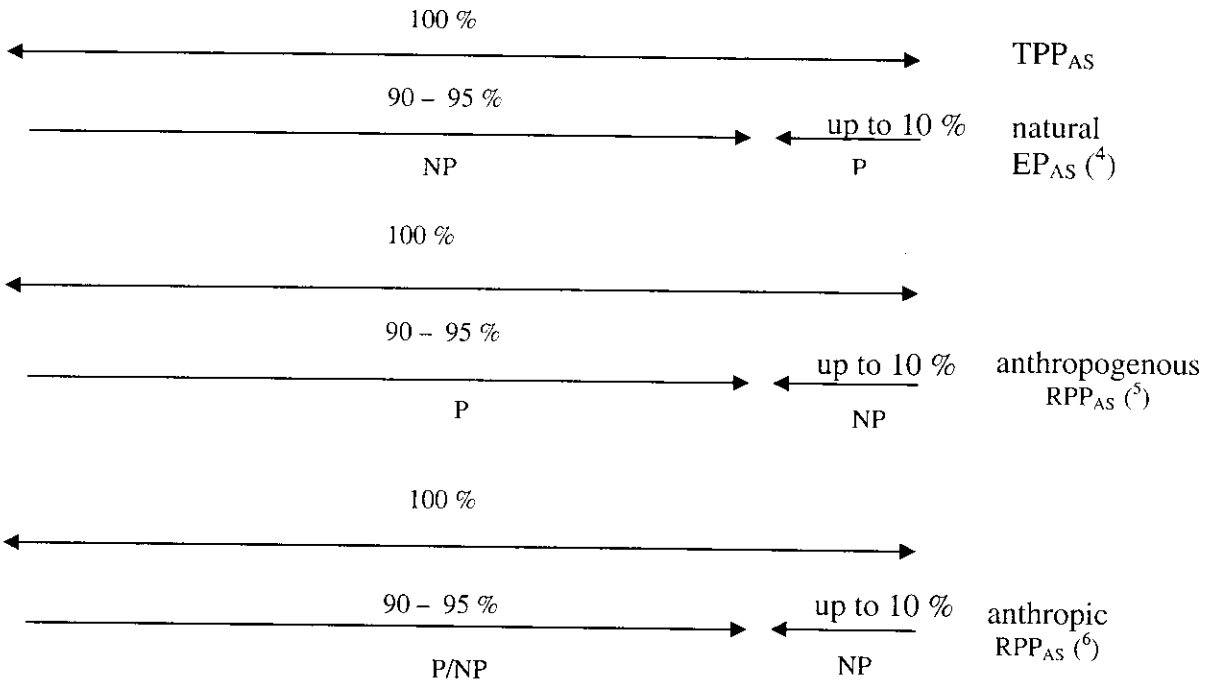


Fig. 1. Algorithm of zonation formula
Obr. 1. Rozhodovací algoritmus pro zonaci

TPP$_{AS}$ – total production potential of agricultural soil – celkový produkční potenciál zemědělské půdy
EP$_{AS}$ – environmental non-production potential of agricultural soil
environmentálny potenciál zemědělské půdy
RPP$_{AS}$ – reduced production potential of agricultural soil
redukovaný produkční potenciál zemědělské půdy
a.s. – agricultural soil – zemědělská půda
P – production function – produkční funkce
NP – non-production function – mimoprodukční funkce

([1]) Rozhodovací spektrum, ([2]) optimalizační mechanismus, ([3]) základní rajonizační vzorec (mezní), ([4]) přírodní celek zemědělské půdy, ([5]) antropoekologický krajinný celek zemědělské půdy, ([6]) antropický celek zemědělské půdy

The interrelation between production and non-production (environmental) components is expressed by zonation formula of the natural potential of the territory or landscape investigated.

Screening of production and non-production functions

Basic indication of environmental functions of soils is allocated in the area of interest with SQUE use including quality parameters. The principle can be applied at three levels. Local, regional and sup-regional pedogenetic associations in this territory are as follows:

- associations of brown forest soils, natural, and brown agricultural soils of cultivated mountain areas
- associations of podzols of mountain type areas cultivated
- associations of peat bog soils
- associations of illimerized podzols, natural and cultivated.

According to the purpose-specifying map, in Prachatice–Vimperk area there are soil types with prevailing ecological functions (tab. 2).

Table 2

Non-production functions of soil types
Mimoprodukční funkce půdních typů

Non-production functions* (1)	Soil type of sub-mountain and mountain areas (8)				
	brown-soils (kambizem) (9)	podzols (10)	peat bogs (11)	illimerized (luvizem) (12)	brown-soil (13)
filtration (2)	25	20	25	55	85
buffering (3)	25	20	40	30	40
transformation (4)					
accumulation (5)	25	30	90	40	50
transport (6)	20	70	20	50	40
reclamation (7)	0	0	0	0	0

*minimum value of function
*minimální hodnota funkce

(1) Mimoprodukční funkce, (2) filtrační, (3) pufrační, (4) transformační, (5) akumulační, (6) transportní, (7) asanační, (8) půdní typy podhorských a horských oblastí, (9) hnědé půdy, (10) podzoly, (11) rašeliništní půdy, (12) illimerizované půdy, (13) hnědozem

Calculation of production value of soils by the method of allocating points (Research Institute for Agricultural Economy in Prague)

This purpose was accomplished by using synthetic parametric method of uniform point allocation method to applicable all SQUE in the Czech Republic:

$$PV_{SQUE} = (P_{MPU} + P_{GT} + P_{SE} + P_{CD}) \cdot C_{CR}$$

where P_{MPU} – point for main unit in the range of 1–50 points
P_{GT} – points for grained texture in the range of 1–25 points
P_{SE} – points for slope (S) and exposition (E) in the range of 0–10 points
P_{CD} – points for stone content (C) and soil depth (D) in the range of 0–15 points
C_{CR} – coefficient for climatic region in the range 0.60 – 1.00

Newly proposed method of total production potential (TPP_{AS}) calculation in agricultural soils

The newly proposed approach for the calculation of the total production potential in agricultural soils consists of the following four steps:

a) *determination of PP_{AS} (the production potential of agriculture soils) calculation*

To determine the formula for the calculation of agricultural soil production potential we used the existing formula for the assessment of soil-climatic properties by the method of allocating points – PV_{SQEU} according to N ě m e c [7]. Thus we found the starting production potential PP_{AS}, which is subsequently modified by means of newly proposed deficit parameters with appropriate point values (tab. 3).

Formula for PP_{AS} calculation

$$SPP_{AS} = PV_{SQUE} = (P_{MPU} + P_{GT} + P_{SE} + P_{CD}) \cdot C_{CR}$$

$$PP_{AS} = SPP_{AS} \cdot (1 - SC_{DP})$$

T a b l e 3

Corrective deficit parameters (C_{DP})
Opravné deficitní parametry (C_{DP})

Corrective parameter (1)	Point value (19)
soils with undeveloped soil profile (2)	0.062
shallow soils (3)	0.062
shallow soils in infiltration area (4)	0.063
permeable and more permeable soils in infiltration area (5)	0.063
moderately skeleton soils (25–50 %) in infiltration area (6)	0.063
soils on slope >17° (7)	0.062
ravines (8)	0.062
slopy soils >12° (9)	0.062
soils on slope 7–12, soil erosion factor >0.48 (10)	0.063
catenas Glr (11)	0.063
flood plain light and plain gleyfied soils in cool and moderately cool region (12)	0.063
gleyfied soils in cool and moderately cool region (13)	0.063
wet gley, peat bog and peaty soils (14)	0.062
catenas (15)	0.062
permeable and more permeable soils of light grain texture dried in accumulation area (16)	0.063
gleyfied soil, flood plain gley soils, mead gley soils, cultivated hydromorphic soils (17)	0.063
sum (18)	1.000

(1) Opravné parametry, (2) půdy s nevyvinutým půdním profilem, (3) mělké půdy, (4) mělké půdy v infiltrační oblasti, (5) propustné a propustnější půdy v infiltrační oblasti, (6) středně skeletovité půdy (25–50 %) v infiltrační oblasti, (7) půdy na svahu >17°, (8) strže, (9) svažité půdy >12°, (10) půdy na svahu 7–12°, faktor erudovanosti >0,48, (11) katény Glr, (12) nivní lehké a nivní glejové půdy v klimatickém regionu chladném a mírně chladném, (13) oglejené půdy v klimatickém regionu chladném a mírně chladném, (14) zamokřené glejové, rašeliništní, zrašelinělé půdy, (15) katény, (16) propustnější a propustné půdy, vysušené v akumulační oblasti, (17) oglejené půdy, nivní půdy glejové, lužní půdy glejové, zkulturněné hydromorfní půdy, (18) součet, (19) bodová hodnota

where PV_{SQUE} – point value SQUE
PP_{AS} – production potential of agricultural soils
SPP_{AS} – starting production potential
C_{DP} – corrective deficit parameter in the range of 0–1 point
P_{MPU} – points for the main unit in the range of 1–50 points
P_{GT} – points for grained texture in the range of 1–25 points
P_{SE} – points for slope (S) and expositions in the range (E), 0–10 points
P_{CD} – points for stone content (C) and soil depth in the range (D), 0–15 points
C_{CR} – coefficient for climatic region, in the range 0.60 – 1.00

T a b l e 4

Corrective environmental coefficients (CE_C)
Opravné environmentální parametry (CE_C)

Environmental function of soils (corrective coefficient) (1)	Point value (2)
biomass production (3)	0.01
filtration (4)	0.02
accumulation (5)	0.045
transformation (6)	0.045
buffering (7)	0.02
transport (8)	0.01
biological basis, genetic pool, reclamation function (9)	0.02
soil as historic medium (10)	0.01
raw material resource (11)	0.01
space for human activities (12)	0.02

(1) Environmentální funkce půd (opravný koeficient), (2) bodová hodnota, (3) produkce biomasy, (4) filtrační, (5) akumulační, (6) transformační, (7) pufrační, (8) transportní, (9) biologická základna, genová rezerva, asanační funkce, (10) půda jako historické médium, (11) zdroj surovin, (12) prostor pro lidskou aktivitu

b) *determination of EP_{AS} (environmental non-production potential of agricultural soils) calculation*

The basis for EP_{AS} determination is the screening of environmental functions included in SQUE contained in the solved region.

The screening shows that the dominant environmental functions are as follows: filtration, buffering, transformation, accumulation, transport, reclamation including, cultivation and landscape forming and anthropogenic function. These functions should be protected and respected in the framework of landscape conservation.

To determine the formula for the calculation of EP_{AS} it is necessary to find the starting environmental potential (SEP_{AS}). Determination of SEP_{AS} is based on the assumption that PP_{AS} + SEP_{AS} = 100 (see fig. 1). Potential SEP_{AS} is subsequently modified by corrected environmental parameter (CE_{LP}). Parameter CE_{LP} is calculated related to formula (see tab. 4)

$$CE_{LP} = SEP_{AS} \cdot SCE_{C}$$

$$\text{then } EP_{AS} = SEP_{AS} + CE_{LP}$$

c) *Determination of the reduced production potential of agriculture soils (RPP_{AS}) calculation*

The potential RPP_{AS} is calculated by the correction of production potential about corrected environmental parameters according to formula

$$RPP_{AS} = PP_{AS} + CE_{LP}$$

d) *The total production potential of agricultural soils (TPP_{AS}) calculation* according to formula

$$TPP_{AS} = RPP_{AS} + EP_{AS}$$

The RPPAS calculation for the area of Vimperk (tab. 5).

Example of SQUE 950110 calculation

95011 belongs to infiltration and accumulation area depending on three deficit parameters (number 5, 12, 16)

$$SPP_{AS} = [PV_{SQUE} = (P_{MPU} + P_{GT} + P_{SE} + P_{CD}) \cdot C_{CR}] = 45\ \%$$

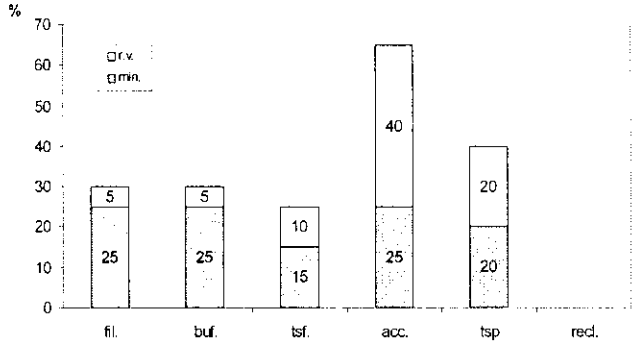


Fig. 2. Brown soil (kambizem) functions in submontain and mountain areas (minimum value of function)

Obr. 2. Funkce hnědé půdy (kambizem) v podhorských a horských oblastech (minimální hodnota funkce)
fil. – filtration – filtrační
buf. – buffering – pufrační
tsf. – transformation – transformační
acc. – accumulation – akumulační
tsp. – transport – transportní
recl. – reclamation – asanační
min. – minimum value – minimální hodnota
r.v. – range of variability – rozsah variability

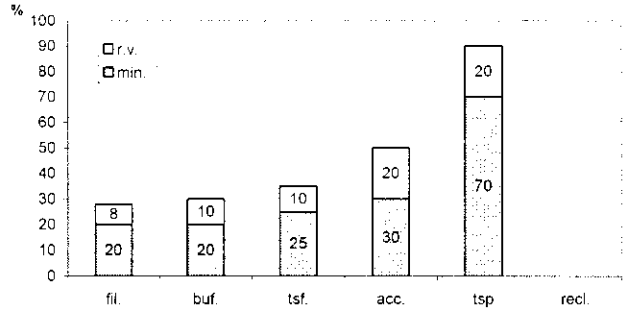


Fig. 3. Podzol functions in mountain a submontain areas. Symbols are identical with figure 2.

Obr. 3. Funkce podzolů v horských a podhorských oblastech. Symboly jako na obrázku 2.

$$PP_{AS} = 45.(1 - 3 \cdot 0.063) = 36\ \%$$

where PP_{AS} is decrease of starting production potential by three deficit parameters SQUE was allocated to the 4th infiltration category – small weight (tab. 7)

→ proposal of agricultural measures: crop rotation and maintaining minimum vegetation cover

Table 5

Calculation of production and environmental potentials of agricultural soil
Výpočet produkčního a environmentálního potenciálu zemědělské půdy

SQUE	Area (1) (m^2)	SP_{PAS} (%)	C_{LP}	PP_{AS} (%)	SEP_{AS} (%)	CE_{LP}	EP_{AS} (%)	RPP_{AS} (%)
936040	115 402	49	0.159	41	59	0.090	64.3	35.7
936210	180 116	53	0.167	44	56	0.090	61.0	39.0
936240	1 924 667	46	0.159	39	61	0.090	66.5	33.5
936310	22 073	52	0.167	43	57	0.090	62.1	37.9
936340	569 809	46	0.159	39	61	0.090	66.5	33.5
936410	43 900	47	0.167	39	61	0.090	66.5	33.5
936440	518 521	41	0.142	35	65	0.090	70.9	29.2
936540	162 941	39	0.159	33	67	0.090	73.0	27.0
937160	132 555	37	0.137	32	68	0.090	74.1	25.9
937460	161 407	31	0.137	27	73	0.045	76.3	23.7
937560	93 270	29	0.137	25	75	0.045	78.4	21.6
939190	6 093	13	0.094	12	88	0.000	88.0	12.0
939290	3 279	13	0.094	12	88	0.000	88.0	12.0
939390	8 468	13	0.089	12	88	0.000	88.0	12.0
940670	50 509	36	0.122	32	68	0.090	74.1	25.9
940680	384 566	27	0.109	24	76	0.045	79.4	20.6
950110	1 072 003	45	0.198	36	64	0.090	69.8	30.2
950140	1 025 605	39	0.188	32	68	0.090	74.1	25.9
950410	90 178	40	0.198	32	68	0.090	74.1	25.9
950440	200 363	37	0.188	30	70	0.090	76.3	23.7
950540	272 603	32	0.188	26	74	0.045	77.3	22.7
968110	280 167	17	0.152	14	86	0.000	86.0	14.0
972010	1 127 554	19	0.152	16	84	0.045	87.8	12.2
973110	455 971	19	0.152	16	84	0.045	87.8	12.2
973130	84 494	14	0.144	12	88	0.000	88.0	12.0
974110	338 943	13	0.171	11	89	0.000	89.0	11.0
in total (2)	9 325 456	30.0		25.0	75.0		78.5	21.5

SQUE – soil quality ecological unit – bonitovaná půdně ekologická jednotka (BPEJ)
SP_{PAS} – starting production potential of agricultural soil
počáteční hodnota produkčního potenciálu zemědělské půdy
C_{LP} – corrective deficit parameter – opravný deficitní parametr
SEP_{AS} – starting environmental potential of agricultural soil
počáteční hodnota environmentálního potenciálu zemědělské půdy
CE_{LP} – corrected environmental parameter – opravný environmentální parametr
PP_{AS} – production potential of agricultural soil – produkční potenciál zemědělské půdy
EP_{AS} – environmental potential of agricultural soil – environmentální potenciál zemědělské půdy
RPP_{AS} – reduced production potential of agricultural soil – redukční produkční potenciál zemědělské půdy

(1) Výměra, (2) souhrn

$$SEP_{AS} = 100 - PP_{AS} = 100 - 36 = 64\ \%$$

$$CE_{LP} = SEP_{AS} + (0.045 + 0.045) = 5.8\ \%$$
(tab. 4 → coefficients 3, 4)

$$EP_{AS} = SEP_{AS} + CE_{LP} = 64 + 5.8 = 69.8\ \%$$

$$RPP_{AS} = PP_{AS} - CE_{LP} = 36 - 5.8 = 30.2\ \%$$

$$TPP_{AS} = RPP_{AS} + EP_{AS} = 30.2 + 69.8 = 100\ \%$$

DISCUSSION AND CONCLUSION

The study presents a new method for determination and evaluation of the total production potential of agricultural soils, which includes the differentiation between production and environmental functions as well as determination of their functional and spatial dimensions. The output consists in so called zonation formulae based on the span of production function and

T a b l e 6

Division of SQUE into the geomorphologic areas in dependence on deficit parameters
Rozdělení BPEJ do geomorfologických oblastí v závislosti na deficitních parametrů

Geomorphological areas (1)	Number of deficit parameters (5)	SQUE
infiltration area (2)	1	93919 93929 93929
	2	93716 93746 92756
	3	93716 93746 92756
	4	93604 93621 93624 93631 93634 93641 93544 93654
	5	93604 93621 93624 93631 93634 93641 93544 93654 95004 95011 95014 95044
transformation area (3)	6	94067 94068
	7	
	8	94067 94068
	9	
accumulation area (4)	10	97411 97643
	11	
	12	95004 95011 95014 95044
	13	96811 97201 97311 97313 97411 97201
	14	97643
	15	
	16	95004 95011 95014 95044

(1) Geomorfologická oblast, (2) infiltrační oblast, (3) transformační oblast, (4) akumulační oblast, (5) číslo deficitního parametru

T a b l e 7

Overview of infiltration category
Celkový přehled kategorie infiltrace

SQUE	Infiltration category (1)	SQUE	Infiltration category
93604	2 – high (3)	93939	1 – very high (2)
93621	3 – medium (4)	94067	3 – medium
93624	2 – high	94068	2 – high
93631	3 – medium	**95011**	**4 – small** (5)
93634	2 – high	95014	3 – medium
93641	2 – high	95041	4 – small
93644	3 – medium	95054	4 – small
93654	3 – medium	96811	4 – small
93716	1 – very high	97201	4 – small
93746	2 – high	97311	4 – small
93756	2 – high	97313	4 – small
93919	1 – very high	97411	4 – small
93929	1 – very high	97643	4 – small

(1) Kategorie infiltrace, (2) velmi vysoká, (3) vysoká, (4) střední, (5) malá

of environmental function. An important part is represented mainly by filtration, accumulation and transport function of water.

Testing the new methodology and the algorithm of calculation took place in the Šumava Mts. marginal area. The obtained data can be utilized in surface water and groundwater protection, in the protection of other natural resources and, last but not least, in creating subsidizing and funding policy, which should comply with the conservation strategies of the state.

Determining the share of particular functions including the relevant risks means important know-how for farmland management, which should be in accordance with the natural potential of the landscape. It enables the state bodies to create nature conservation policy on an objective basis, including the protection of water resources.

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SOUHRN

V práci je představena nová metoda k vymezení a hodnocení celkového produkčního potenciálu zemědělských půd CPP_{zp}. Navrženy jsou nové pedologické vrstvy z hlediska potřeby vymezení degradačních parametrů u hlavních půdních představitelů pro následnou limitaci produkčního potenciálu (delimitační parametr, blokační a homogenizační parametr, hydromorfizmus, degradace půdní struktury a stavby, erozní ohroženost, skeletovitost, infiltrační schopnost půd).

Teoretickým základem pro výpočet CPP_{zp} je definice produkčních a environmentálních funkcí v zemědělské krajině, návrh metodického postupu pro výpočet uvedených funkcí a konstrukce výpočtových vzorců, včetně stanovení bodového rozpětí pro jednotlivá čísla kódu bonitované půdně ekologické jednotky, resp. hlavní půdní jednotky. U produkční funkce byly nově navrženy opravné koeficienty pro deficitní parametry, u výpočtu environmentální funkce jsou navrženy opravné environmentální parametry.

Výstupem z navrženého postupu je stanovení tzv. rajonizačních vzorů, které jsou tvořeny rozpětím produkční funkce a z rozpětí určené pro environmentální funkce zemědělských půd. Za účelem objektivního posouzení nově navrhovaného metodického postupu i vlastního algoritmu výpočtu bylo přistoupeno k praktickému ověření v marginální oblasti Šumava–Zdíkovsko. Ověřením se prokázalo, že nově navržený postup zabezpečuje získání relevantních grafických i textových výstupů s vysokou vypovídací schopností. Dosažený stupeň přesnosti – prostorová rozlišovací úroveň, odpovídá požadavkům mapové projekce s tím, že další zpřesnění je vázáno na použití moderního softwéru. Náročnost nově navrženého postupu je srovnatelná se stávajícím postupem, a to jak co do technického zázemí, tak i z hlediska časové náročnosti při získání výstupů s prokazatelně vyšší kvalitou i exploatační hodnotou.

Klíčová slova: environmentální funkce, celkový produkční potenciál, bonitovaná půdně ekologická jednotka