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PARAMETERIZATION OF CROP SIMULATION MODEL "CERES-MAIZE" IN NITRA-DOLNÁ MALANTA

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Abstract. Nowadays more than ever production of food depends on reasonable usage of sources. Processes like climate change, climate variability, carbon retention, long-time food safety are becoming more and more important. Determining of reasonable crop strategy can have a significant social and economic effect. Computer-simulative models of systems soil/plant/atmosphere can help in processes like crop growth or development. Crop simulation model CERES-Maize program part of DSSAT v.4 was used to simulate potential maize grain yield. Field trials of Slovak Agricultural University in Nitra – Dolna Malanta were used for parameterization of the model. Model inputs included TMIN-minimal daily temperature, TMAX-maximal daily temperature, SRAD-sun radiation and RAIN-daily sum of precipitation called as ´minimum data set´ were built into weatherman program shell. These weather data are basic for the model running. Other important input data included the soil data and agrotechnological data. Outputs of the model show that measured and simulated maize grain yields have a very close relationship. Mean relative difference from all these years reached 7,76 %. Simulated grain yields are a little bit higher in all years as compared with field trial yields. This fact can be explained by the influence of a harmful disease and insects. Successful parameterization is a good base for climate change impact studies.

Keywords: crop modeling, DSSAT 4, CERES-Maize, parametrization, weather, soil, agrotechnology.

1. Introduction

Nowadays more than ever production of food depends on reasonable usage of sources. Processes like climate change, climate variability, carbon retention, long-time food safety are becoming more and more important. Determining of reasonable crop strategy can have a significant social and economic effect. Computer-simulative models of systems soil/plant/atmosphere can help to understand processes like crop growth or development. Weather plays a primary role in productive process of field crops. It influences crop yields and its quality. Maize (*Zea Mays* L.) is a very productive and perspective crop for future [1]. That is why knowing of its productive process could be very essential in changing climatic conditions. Parametrization of crop simulation models can show the future yield development.

DSSAT v4.0 is an upgrade of the DSSAT v3.5 system which was released in 1999. One of the main changes and improvements in DSSAT v4 is that it has been completely redesigned and now it is MS Windows-based. All shell, application programs and data entry and analysis tools have been rewritten to be compatible with the latest Windows standards. In addition, all crop models were combined into the Cropping System Model (CSM) which is based on a modular modeling approach. CSM uses one set of code for simulating soil water, nitrogen and carbon dynamics, while crop growth and development are simulated with the CERES, CROPGRO, CROPSIM and SUBSTOR modules. The CENTURY-based soil carbon and nitrogen model for improved performance in low input agricultural systems, and for simulation carbon sequestration was added as a separate soil module to CSM. The crop models of DSSAT v3.5 are included in DSSAT v4.0 as legacy models for user comparison and analysis [2].

The CERES-Maize crop model was used to simulate potential maize grain yield. This model is a dynamic crop model that simulates plant response to the soil, weather, water stress and management practices. The model calculates development, growth and partitioning processes on a daily basis, beginning with planting and ending at harvest maturity.

2. Investigation object and methodology

CERES-Maize is a crop simulation model a part of DSSAT 4 (Decision support system for agrotechnology transfer version 4) which requires many input data. These data are essential for parameterization of the CERES-Maize crop simulation model. Field trials of Slovak Agricultural University in Nitra-Dolna Malanta were used for parameterization of the model. The study area is located approximately 3 km eastward from Nitra. The whole area is situated in the south western part of Slovakia with an altitude of 171 m, at latitude 48°19´ north and at longitude 18°07´east. The whole territory of Slovakia lies in a moderate-climate zone with partial influence of the Atlantic

Ocean and Eurasian continent. This fact is reflected in yearly precipitation totals 538 mm (1961– 90) and mean air temperature of 9,8 °C [3]. The selected region lies on the edge of Danubian lowland and Zitavska upland.

Climatic conditions are favourable for maize growing and that is why this area is known in Slovakia as a maize agroclimatic zone. Maize belong to a smaller group of plants the primary photosynthesis product of which is carboxyl acid. This molecule consists of four atoms of carbon "C". This fact is common for all plants of this group, such as amaranthus, sorghum, millet, and sugarcane, and they are called as C4 plants.

As it was mentioned above the CERES-Maize model requires particular data to run a simulation. These data are represented by groups of weather, physiological, soil and agrotechnological informatikon.

Weather data

Weather data are considered as essential data, and the model cannot be run without them. Weather data are managed by special utility program Weatherman, a part of DSSAT 4 program. In this study meteorological dataset included solar radiation SRAD [MJ/day], maximal day air temperature TMAX [°C], and minimal day air temperature TMIN [°C], daily sum of precipitation RAIN [mm] and relative sunshine hours SUNH [%]. All these meteorological data were measured by a conventional weather station situated in Dolna Malanta [4–7]. Nowadays a new automatic weather station AWS 200 is in trial service and data from this station are analysed and will be used in future. An example of input meteorological data is shown in Fig 1.

Physiological data

These data are represented mostly by crop and cultivar. In our case cultivar LG 23.06 was used. This cultivar was made by a breeding company Limagrain Genetics Grandes Cultures S.A., in France. Its usage is especially wide in maize and sugar beet agroclimatic productive zones. It is a cultivar with a medium short vegetative season with the FAO number 310. Grain type is a horse's tooth. Plant population for this cultivar was 8 plants per square meter which is a number very close to 8,5 recommended by a breeding company.

Soil data

The soil type in Dolna Malanta is loamy clay with these diagnostic layers:

Stratigraphy of soil profile: Al – depth 0,0–0,32 m light brown (10YR 5/4), crumb structure, wet, loose, loamy, uncarbonate, with many roots, the number of elements smaller than 0,001 mm;

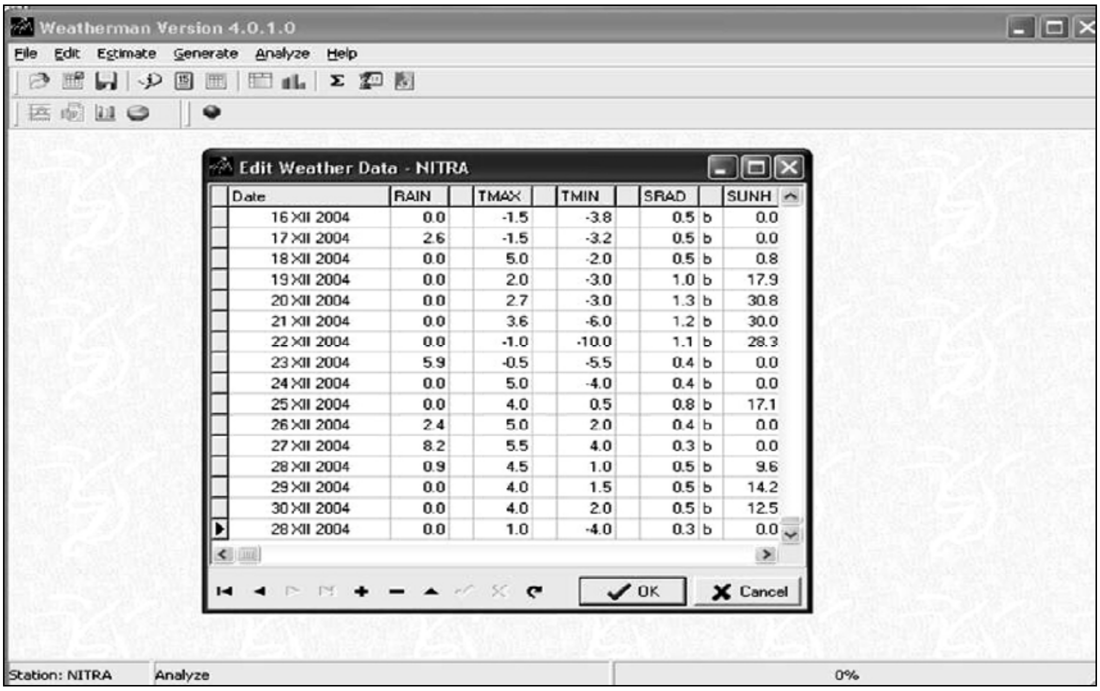
Bt – depth 0,33–0,65 m, rusty brown (10YR 5/6), cubic structure, wet, compact, loamy clay, uncarbonate, with few roots, the number of elements smaller than 0,001 mm reaches higher values (51,70–59,70 %) Bt/C – depth 0,66–0,85 m, yellow brown (10YR 6/4), cubic structure, wet, compact, loamy, uncarbonate, with quartz sand wet, compact, carbonate with mean pH 6,73 (Hanes et.al., 1993);

C – depth over 0,86 m, yellow (10YR 7/6) null structure, wet, compact, carbonate [8].

All these soil data were built into a soil program Sbuild.

Physical soil properties

The soil specific weight of the selected area varies 2580–2660 kg·m^{-3}. This specific weight is favourable for planted crops. The volume of the mentioned fraction is in the range 32,83–41,20 %. The number of particles smaller than 0,001 mm are in the range 15,56–22,17 %. Between humus and luvic horizons that means that at



Date	RAIN	TMAX	TMIN	SRAD		SUNH
16 XII 2004	0.0	-1.5	-3.8	0.5	b	0.0
17 XII 2004	2.6	-1.5	-3.2	0.5	b	0.0
18 XII 2004	0.0	5.0	-2.0	0.5	b	0.8
19 XII 2004	0.0	2.0	-3.0	1.0	b	17.9
20 XII 2004	0.0	2.7	-3.0	1.3	b	30.8
21 XII 2004	0.0	3.6	-6.0	1.2	b	30.0
22 XII 2004	0.0	-1.0	-10.0	1.1	b	28.3
23 XII 2004	5.9	-0.5	-5.5	0.4	b	0.0
24 XII 2004	0.0	5.0	-4.0	0.4	b	0.0
25 XII 2004	0.0	4.0	0.5	0.8	b	17.1
26 XII 2004	2.4	5.0	2.0	0.4	b	0.0
27 XII 2004	8.2	5.5	4.0	0.3	b	0.0
28 XII 2004	0.9	4.5	1.0	0.5	b	9.6
29 XII 2004	0.0	4.0	1.5	0.5	b	14.2
30 XII 2004	0.0	4.0	2.0	0.5	b	12.5
28 XII 2004	0.0	1.0	-4.0	0.3	b	0.0

Fig 1. Meteorological inputs to model from weatherman program

a depth of 0,30–0,40 m the values of specific weight are higher and exceed the critical level for loamy clay horizons (over 1400 kg·m^{-3}). Values vary 1470–1530 kg·m^{-3}. This fact shows bad soil properties of this soil layer.

All these specific weight values are in close relationship with the soil porosity values (Pc %). Below the critical border (<45 %) are especially at a depth of 0,30–0,40 m. At this depth the content of uncapillary pores is remarkably decreased, and the values of minimal air capacity are below the critical level (<10 %).

Basic hydrophysical soil properties

The soil hydrophysical properties correspond with basic properties, especially with capillary porosity and soil specific weight. The values of fading point vary 10–15 % in humus horizon, in the layer under plow they are 12–16 % and are favourable for the soil water usage. Retention water capacity and maximal capillary water capacity are favourable as well. Reached values 25–35 % usually do not exceed the critical value of 35 % and show a high retention potential and high values of the soil water capacity. This state of hydrophysical properties is very positive for planted crop and water accessibility to their roots [8, 9].

Chemical soil properties

Organic matter in the soil is accumulated, especially in humus horizon (Al), where humus content reaches 1,95–2,60 % what is 2,16 % on the average. Humus content in the soil decreases rapidly with depth, and in the layer under plow it is just 0,79 % on the average.

Al- horizon is of fulvatic-humus type where humin acids (HA) prevail over fulvo acids (FA). Their ratio is 1,12:1. With the depth of soil profile more water-soluble fulvo acids occur in a higher amount, and a lower quality of humus is formed. This fact is reflected in HA : FA ratio that is 0,8 to 0,46:1 according to the soil depth.

The pH of humus horizon is acidic and varies from 5,03 to 5,69 with mean pH 5,36.

In Bt/C the soil pH is of acidic to neutral character and is 5,97. In C horizon the soil has neutral to acidic properties with average pH 6,73. Difference between the upper humus horizon and down C horizon is 1,37 units of pH [8].

Agrotechnological information

This type of information includes crop rotation, tillage, irrigation, amount of fertilizers, plant density, day of planting and harvesting [10, 11]. Particular values changed year by year and are shown in Table 1.

Table 1. Agricultural inputs to model

Year	Planting date	Population density /m^2	Harvest	Tillage date	Previous crop	Fertilizers	Application date, amount of fertilizers in kg/ha
2001	26.4	8	10.10	31.10.00	Pea	KCl	30.10, 20 kg/ha
						1SP	30.10, 15 kg/ha
2002	23.4	8	9.10	19.10.01	Pea	CAN	23.4, 60–70 kg/ha
2003	23.4	8	13.10	21.10.02	Pea	CAN	6.6, 40–50 kg/ha
						1SP	12.5, 44 kg/ha
2004	29.4	8	30.10	27.10.03	Pea	1SP	20.5, 35–40 kg/ha
						CAN	25.4, 60–70 kg/ha

(KCl – calcium chloride, 1SP – single super phosphate, CAN – calcium ammonium nitrate solution)

Table 2. Grain yields and deviations

Year	Agrotechnological variant	Measured t/ha	Simulated t/ha	Absolute deviation	Relative deviation (%)
2001	B1	7.91	8.27	0.36	4.35
	B2	7.28	8.18	0.90	11.00
	B3	5.96	6.57	0.61	9.28
2002	B1	11.10	11.89	0.79	6.64
	B2	11.70	12.25	0.55	4.49
	B3	11.52	11.96	0.44	3.68
2003	B1	9.13	9.36	0.23	2.46
	B2	8.99	9.47	0.48	5.07
	B3	8.12	9.15	1.03	11.26
2004	B1	9.36	10.17	0.81	7.96
	B2	10.58	11.23	0.65	5.79
	B3	7.59	9.63	2.04	21.18

Table 3. Example of model output

Main growth and development variables	
VARIABLE	SIMULATED
Anthesis day (dap)	88
Physiological maturity day (dap)	171
Yield at maturity (kg [dm]/ha)	10627
Number at maturity (no/m^2)	2175
Unit wt at maturity (g [dm]/unit)	0.4887
Number at maturity (no/unit)	362.4
Top weight at maturity (kg [dm]/ha	19193
By-product harvest (kg [dm]/ha)	8566
Leaf area index, maximum	4.25
Harvest index at maturity	0.554
Grain N at maturity (kg/ha)	0
Top N at maturity (kg/ha)	0
Stem N at maturity (kg/ha)	0
Grain N at maturity (%)	0.0
Top weight at anthesis (kg [dm]/ha	7397
Top N at anthesis (kg/ha)	0
Leaf number per stem, maturity	22.25
	10627 kg/ha [DRY WEIGHT]

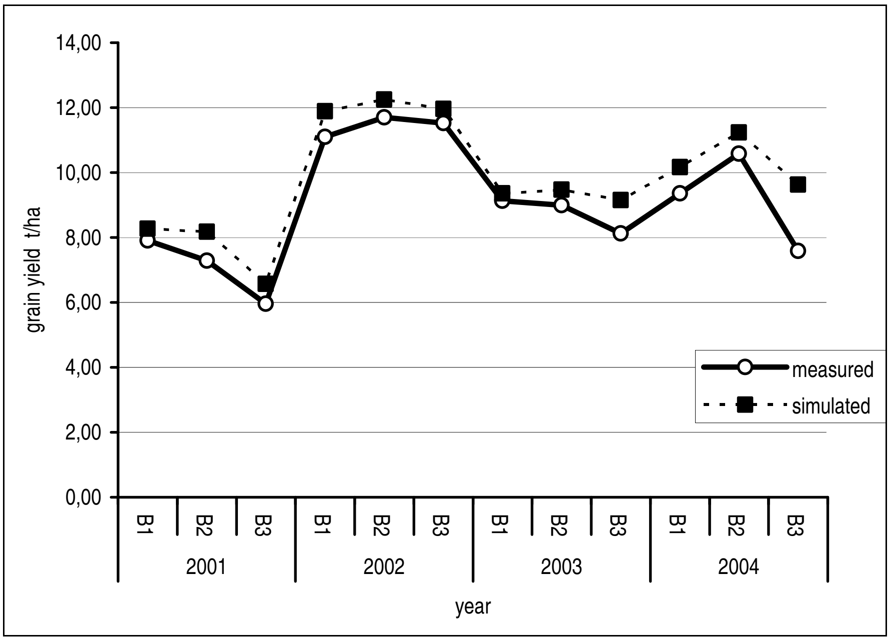


Fig 2. Measured and simulated grain yields in Dolna in Malanta in 2001–2004

3. Results and discussion

According to inputs on weather, physiological, soil and agrotechnical data, dataset was built for simulation by a program ICSim. This simple program integrates all the input data mentioned above and enables to run easy simulations. Simulations were made for the years 2001–2004. The potential maize grain yields – output from a model, were compared with measured grain yields from the years 2001–2004 (Table 2). Comparison was made on the PH variant (a variant with synthetic fertilizers). Field trials consist of 3 subvariants (B1 conventional tillage, B2 rational tillage, B3 tillage with dish harrow) differing in the amount and type of applied fertilizers (Table 3). Fig 2 shows measured and simulated maize grain yields.

4. Conclusion

Measured and simulated maize grain yields show a good relationship in explanatory school fields in Dolna

Malanta. Simulated grain yields are higher for all the years. Mean year differences reached the following values: 8,21 % – in 2001, 4,94 % – in 2002, 6,26 % in 2003 and 11,65 % – in 2004. Extreme meteorological events were not taken into account in these simulations. This parametrization represents a good starting point for climate change simulations and can help to find effective strategy for solution of possible global food crisis in conditions of Central Europe.

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References

1. ANTAL, J.; KOVÁČ, K.; IGAZ, D. Effect of cultivation and crop rotation on partitioning of N-NO_3 in October 1996. In *Effect of antropogenic activity on water regime of lowland area*. UH-SAV, Bratislava, 1999, p 230–240.
2. TSUJI, G. Y.; JONES, J. W. and BALAS, S (eds). *DSSAT v3*. Vol 3. University of Hawaii, Honolulu, Hawaii, 1994, 244 p.
3. ŠIŠKA, B.; IGAZ, D. CH_4 emission from agricultural sources and possibilities of their reduction in Slovakia. In *Acta Horticulture et regiotecturae*, 2002, Vol 5, No 1, p 20–23.
4. REPA, Š.; ŠIŠKA, B. *Climatic charactetics of 2001 in Nitra*. 11. VES SPU Nitra, 2002. 30 p.
5. REPA, Š.; ŠIŠKA, B. *Climatic charactetics of 2003 in Nitra*. 13. SPU Nitra, 2004. 24 p.
6. ŠIŠKA, B.; REPA, Š. *Climatic charactetics of 2000 in Nitra*. VES SPU Nitra, 2001. 30 p.
7. ŠIŠKA, B.; REPA, Š. *Climatic charactetics of 2002 in Nitra*. VES SPU, 2003. 32 p.
8. HANES, J.; MUCHA, V.; SISAK, P.; SLOVIK, R. *Characteristic of soil of research experimental basis AF VŠP Nitra Dolná Malanta*. Nitra, VES VŠP, 1993.
9. ŠIŠKA, B. et al. *Praktická biometeorológia*. Nitra SPU, 2002. 104 p.
10. TSUJI, G. Y.; JONES, J. W. and BALAS, S. (eds.). *DSSAT v3*. Vol 1. University of Hawaii, Honolulu, Hawaii, 1993. 164 p.
11. TSUJI, G. Y.; JONES, J. W. and BALAS, S. (eds.). *DSSAT v3*. Vol 2. University of Hawaii, Honolulu, Hawaii, 1994, p 284.

PASĖLIŲ MODELIAVIMO MODELIO *CERES-MAIZE* PARAMETRIZAVIMAS NITRA DOLNÁ MALANTOJE

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Santrauka

Pastaruoju metu labiau nei bet kada maisto gamyba turi būti pagrįsta tinkamu išteklių panaudojimu. Vis svarbesni tampa tokie procesai, kaip klimato šiltėjimas, jo nepastovumas, anglies kaupimasis ir saugus maisto produktų laikymas ilgą laiką. Nustačius pagrįstą pasėlių auginimo strategiją, galima pasiekti žymų socialinį ir ekonominį efektą. Kompiuteriniai sistemos dirvožemis–augalas–atmosfera modeliai gali padėti auginant pasėlius ar plečiant jų plotus. Potencialiam kukurūzų grūdų derliui modeliuoti buvo taikytas pasėlių modelis *CERES-Maize*, kuris yra dalis *DSSAT*. Slovakijos žemės ūkio universiteto Nitra Dolna Malantoje lauko sąlygomis atliktų tyrimų duomenys buvo naudoti modeliui parametrizuoti. Modelio įvesties duomenis sudarė *TMIN* – minimali dienos temperatūra, *TMAX* – maksimali dienos temperatūra, *SRAD* – saulės radiacija ir *RAIN* – suminiai dienos krituliai. Tai vadinamasis minimalus duomenų rinkinys, kurio reikia meteorologinėms sąlygoms aprašyti, jis yra būtinas sėkmingam modeliavimui. Kiti svarbūs įvesties duomenys – dirvožemio ir agro-technologiniai duomenys. Modelio rezultatai parodė, kad apskaičiuotasis ir sumodeliuotasis kukurūzų grūdų derliai yra glaudžiai susiję. Vidutinis santykinis nuokrypis per visus šiuos metus siekė 7,76 %. Sumodeliuotas grūdų derlius visais metais buvo šiek tiek didesnis, palyginti su lauko eksperimentų duomenimis. Tokius rezultatus galima paaiškinti pavojingų ligų ir vabzdžių antpuoliu. Sėkmingas modelio parametrizavimas gali tapti puikiu pagrindu studijuojant klimato kaitos poveikį.

Reikšminiai žodžiai: pasėlių modeliavimas, *DSSAT 4, CERES-Maize*, parametrizavimas, oro sąlygos, dirvožemis, žemės ūkio technologijos.

ПАРАМЕТРИЗАЦИЯ МОДЕЛИ “CERES-MAIZE” ДЛЯ МОДЕЛИРОВАНИЯ УРОЖАЯ ЗЕРНА В НИТРЕ (ДОЛНА МАЛАНТА)

П. Самугел, Б. Шишка

Резюме

В последнее время больше чем когда-либо производство пищевых продуктов должно быть основано на правильном использовании природных ресурсов. Все более важными становятся такие процессы, как потепление и неустойчивость климата, скопление углерода и безопасность пищевых продуктов. Определив обоснованную стратегию для производства зерна, можно достичь значительного социального и экономического эффекта. Компьютерные модели системы почва/растение/атмосфера могут способствовать выращиванию посевов и расширению их площадей. Для моделирования потенциального урожая кукурузы была применена модель “CERES-Maize” , являющаяся 4-й частью DSSAT. Для параметризации модели были использованы данные, полученные во время эксперимента, проводившегося в полевых условиях в Словацком аграрном университете в городе Нитре (Долна Маланта). Исходными данными модели были TMIN – минимальная температура дня, TMAX – максимальная температура дня, SRAD – солнечная радиация, RAIN – суммарные осадки дня. Это так называемый набор минимальных данных, необходимых для описания метеорологических условий и успешного моделирования. Другими важными исходными данными являлись аграрно-технологические свойства и данные почвы. Результаты показали, что измеренный и смоделированный урожаи зерна аналогичны. Среднее относительное отклонение за все время составило 7,76 %. Смоделированный урожай был несколько больше по сравнению с данными эксперимента. Это можно объяснить возможностями опасных болезней растений и вредом, наносимым насекомыми. Успешная параметризация модели может стать основой для исследования влияния потепления климата.

Ключевые слова: моделирование урожая зерна, DSSAT 4, "CERES-Maize", параметризация, погода, почва, аграрные технологии.

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