REDUCED VERSION

Title: Introduction of crop modelling tools into a Serbian crop production

Place: BOKU, Vienna, Austria
Date: 1.12.2005.

Reduced version: Faculty of Agriculture, University of Novi Sad
Date: 8.2.2006.

First report: Faculty of Agriculture, University of Novi Sad
Date: 30.06.2006.

Final report: Faculty of Agriculture, University of Novi Sad
Date: 30.10.2006.

Participant /User: Dr Branislava Lalic, Department for field and vegetable crops, Faculty of agriculture, University of Novi Sad, Novi Sad, Serbia and Montenegro

Joint projects: Research institute for field and vegetable crops, Novi Sad

Main goal: Application of crop modelling tools in estimating climate variability impact on crop production

Objective I – Teaching

Motivation: Introduction of crop models in Serbian agriculture through the educational process. It is very important task that future engineers of agriculture have some basic knowledge related to application of crop models in agricultural production.

Activities: **Preparation of** useful **text books** and handouts based on crop models books, manuals and published papers to provide short overview of crop models and detailed description of one or two frequently used and well elaborated models.

Results: **Lecturenotes** following lectures and exercises in Crop modelling.

Users: Students of agriculture

As an element of dissemination activities of this pilot project last four clases of Meteorology course for undergraduate students at Faculty of Agriculture (University of Novi Sad) will be devoted to crop modeling. Also, lectures as well as class material will be published at the Faculty web page.

Objective II – Research

Motivation: Application and validation of different crop models using results of field experiments carried out with Serbian crop sorts at certain agroecological conditions.
Activities:

a) **Provide an overview** of weather and crop data necessary to running crop models.
b) **Assimilate crop data** from field experiments carried out at experimental fields of Research institute for field and vegetable crops at Rimski Sancevi (Novi Sad, Serbia) **and weather data** from meteorological station Rimski Sancevi in the vicinity of experimental fields (less that 1 km on flat terrain). **Soil wetness** necessary for running some models will be calculated running LAPS scheme with measured weather data and measured initial soil wetness.
c) **Calibrate SIRIUS and WOFOST (PERUN) crop models** using observed data.
d) **Compare** different model outputs, and check their availability to reproduce observed crop growth, yield and yield components.
e) **Run** chosen **models** to **test** their **sensitivity** on some parameters and **estimate impact** of climate variability on crop yield in Vojvodina region.

Results: Calibrated WG and crop models for our agroecological conditions.
Users: Scientist working on improvement of agricultural production; engineers in agricultural advisory services; people in seed production institutes and companies

Realisation:

a) Weather data series were provided for the Rimski Sancevi weather station (synop code 13168) for period 1948 – 1999. Radiation was calculated using Prescott's empirical relation with coefficients determined for Novi Sad region (Mihailovic and Acs, 1985). Weather data series are properly formatted and run using Met&Roll and LARS weather generators. Met&Roll weather generator was tested in detail for different WG parameters and climate scenarios for Novi Sad. In Tab. 1 are indicated periods, WG parameters (included climate scenario or CO_2 increase) and file_names used to indicate certain weather serie.

No.	Data series	Scenario	CO_2	file_name.wtx
WG1	1960-2010	NO	NO	g60_10
WG2	1960-2010	YES	NO	g6010s110
WG3	1960-2010	YES	YES	g6010s11350
WG4	1980-2010	NO	NO	g80_10
WG5	1980-2010	YES	NO	g8010s110
WG6	1980-2010	YES	YES	g8010s11350
WG7	1990-2010	NO	NO	g90_10
WG8	1990-2010	YES	NO	g9010s110
WG9	1990-2010	YES	YES	g9010s11350

Table 1 Weather data series and WG parameters combination used to provide generated weather.

In order to quantify the generated weather data an error analysis, based on a method discussed in Pielke (1984) and later used by Mahfouf (1990) and Mihailovic et al. (2000) has been performed. For one particular year (2004.), standard deviations of generated and observed data (? and ?) as well as root-mean-square errors, RMSE (?) related to daily precipitation ($?_H, ?_H, ?_H$), maximum ($?_{Tmax}, ?_{Tmax}, ?_{Tmax}$) and minimum ($?_{Tmin}, ?_{Tmin}, ?_{Tmin}$) air temperature, were calculated. Following Pielke

No.	? $_{Tmax}$	? $_{Tmax}$	? $_{Tmax}$	? $_{Tmin}$	? $_{Tmin}$	? $_{Tmin}$	? $_{H}$	? $_{H}$	? $_{H}$
WG1	9.95	**9.89**	6.99	7.33	**7.44**	5.32	15.52	15.66	9.13
WG2	9.95	10.19	7.26	7.33	7.53	5.50	15.52	17.16	9.04
WG3	9.95	10.19	7.26	7.33	7.53	5.50	15.52	17.16	9.04
WG4	9.95	10.23	7.07	7.33	8.00	**4.96**	15.52	16.99	8.16
WG5	9.95	10.50	7.49	7.33	8.07	5.01	15.52	18.58	8.20
WG6	9.95	10.50	7.49	7.33	8.07	5.01	15.52	18.58	8.20
WG7	9.95	11.43	**6.90**	7.33	8.05	5.14	15.52	**15.44**	**7.30**
WG8	9.95	11.79	7.15	7.33	8.16	5.01	15.52	17.06	7.33
WG9	9.95	10.87	7.49	7.33	8.01	5.29	15.52	18.09	8.11

Table 2 Error analysis of generated and observed weather data during the year 2004 for nine data sets.

(1984), the values of ? and ? should be close if the simulation is to be considered realistic. The statistics for generated and observed weather data during the year 2004 are listed in Table 2. It indicates that the smallest value of RMSE for T_{max} and H corresponds to WG7, while for T_{min} it is a WG4 data series. A comparison of ? and ? for T_{max}, T_{min} and H shows that difference between them is smallest for WG1 data serie. It refers that weather data generated using WG1, WG4 and/or WG7 series, or some combination of it, can provide the best correspondence to observed weather.

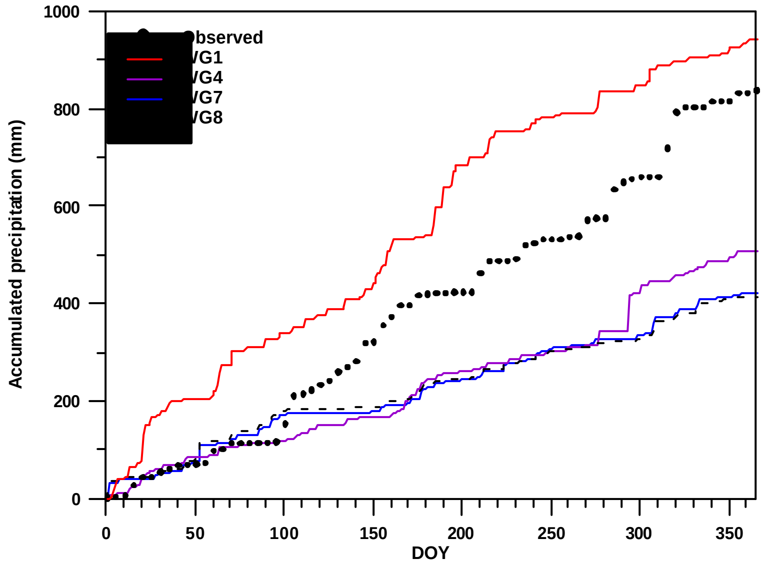

Figure 1 Accumulated precipitation calculated using observed and by PERUN generated data for WG1, WG4, WG7 and WG8 data series

Since time distribution and accumulation of precipitation is more important, for agrometeorological purposes, then daily amount of precipitation, an analysis of accumulated precipitation for different data sets for year 2004 was performed (Fig. 1). From fig. 1 it is seen that WG1 data set exerts smallest deviation from observed trend of accumulated precipitation, while in case of WG4, WG7 and WG8 could be noticed an excelant match between observed and generated precipiatation in first 100 days.

b) A first and very important step in running crop models is to provide input data. An overview of weather, soil, crop and management data necessary to runn SIRIUS and PERUN models are presented in Tabs. 3 and 4.

Weather data	Soil data	Crop data	Management
min. air temperature	saturation moisture content	thermal time from sowing to emergence	sowing date
max. air temperature	drained upper limit	thermal time from anthesis to beginning of grain fill	soil name
precipitation	lower limit	thermal time from beginning to end of grain fill	cultivar
radiation	percolation coefficient	thermal time from end of grain fill to harvest maturity	RUE or CO2 concentration
wind speed	mineralisation constant	potential maximum leaf size	number of management applications
vapour pressure	organic N	phyllochron in degree days	Irrigation and fertilization dates and amounts
	minimum mineral N content of soil	minimum possible leaf number	initial moisture deficit
	constant for denitrification pulse	absolute maximum leaf number	amount of inorganic N
	amount of inorganic N	daylength response in leaves per hour of daylength	proportion of Ni in the Top (33%) and Mid (33%) soil
		response of vernalisation rate to temperature	
		vernalisation rate at 0 C	
		PAR extinction coefficient	
		max. protein conc. in unlimited growth conditions	

Table 3 Overview of weather, soil, crop and management data in SIRIUS crop model.

Weather data	Soil data	Crop data	Management
min. air temperature	vol. soil moisture content	lower threshold temp. for emergence	sowing date
max. air temperature	soil moisture content at wilting point,	max. eff. temp. for emergence	soil name
precipitation	soil moisture content at field capacity	temperature sum from sowing to emergence	cultivar
radiation	soil moisture content at saturation	pre-anthesis development depends on temp., daylength or both	number of production levels
wind speed	critical soil air content for aeration	optimum daylength for development	type of water limited crop growth
vapour pressure	hydraulic conductivity of saturated soil	critical daylength	type and amount of fertilizer applied
	maximum percolation rate root zone	temperature sum from emergence to anthesis	
	maximum percolation rate subsoil	temperature sum from anthesis to maturity	
	1st topsoil seepage parameter deep seedbed	daily increase in temp. Sum as function of av. temp	
	2nd topsoil seepage parameter deep seedbed	development stage at harvest	
	1st topsoil seepage parameter shallow seedbed	initial total crop dry weight	
	2nd topsoil seepage parameter shallow seedbed	leaf area index at emergence	
	required moisture deficit deep seedbed	maximum relative increase in LAI	
		specific leaf, pod. and steam area	
		life span of leaves growing at 35 Celsius	
		lower threshold temp. for ageing of leaves	
		extinction coefficient for diffuse visible light	
		light-use effic. single leaf	
		efficiency of conversion of assimilates into leaves, storage org., roots and stems	
		relative maintenance respiration rate for leaves, storage org., roots and stems	
		fraction of total dry matter to roots and storage organs	
		death rates	
		water use	
		rooting	
		maximum and minimum concentrations of N, P, and K in storage and vegetative organs	

Table 4 Overview of weather, soil, crop and management data in PERUN crop model

c) All important crop, management and site information for one typical sort of winter wheat – Anastasia, grown on experimental fields of Institute for Field and Vegetable Crops at Rimski Sancevi (Novi Sad, Serbia) were provided for 2001-2005 growing periods.

d.1) *Results of SIRIUS crop model calibration*

For the purpose of SIRIUS crop model calibration following data were assimilated: phenology phases exact dates, biomass and grain mass and yield. For each growing season during the 2001-2005 period, for winter wheat Anastazija, were calculated dates of following phenology phases: emergence, anthesis, begin of grain fill, end of grain fill and maturity. Achieved results are compared with observed dates of growth stage appearance and presented on Fig. 2. Even short inspection of this figure shows that there is a perfect match between calculated and observed dates. This fact is very important one since accurate forecasting of phenology dynamic can improve efficiency of farm management operations.

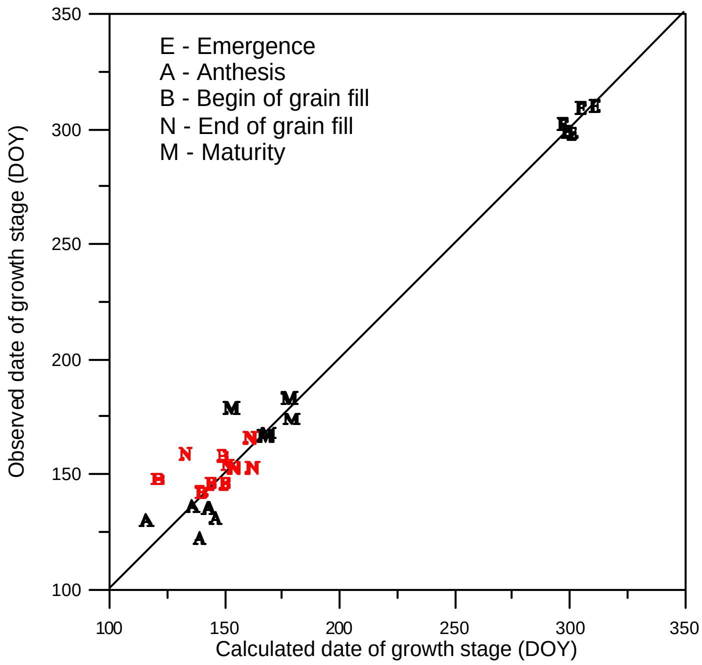

Figure 2 Comparison of dates of phenology phases calculated using SIRIUS crop model and observed for winter wheat Anastazija during 2001-2005 vegetation periods

Results achieved for biomass development for Anastasia winter wheat (Fig 3) show non significant deviation of calculated vs. observed biomass, but there is a systematic rush-in of simulated values. Could be supposed at least two possible sources of problem noticed: 1) error in parameterisation of radiation can cause overestimation of PAR and/or 2) overestimation of PAR interception coefficient can cause overestimation of intercepted PAR. Since biomass production in SIRIUS is related to intercept PAR one or both errors can produce rush-in of simulated values.

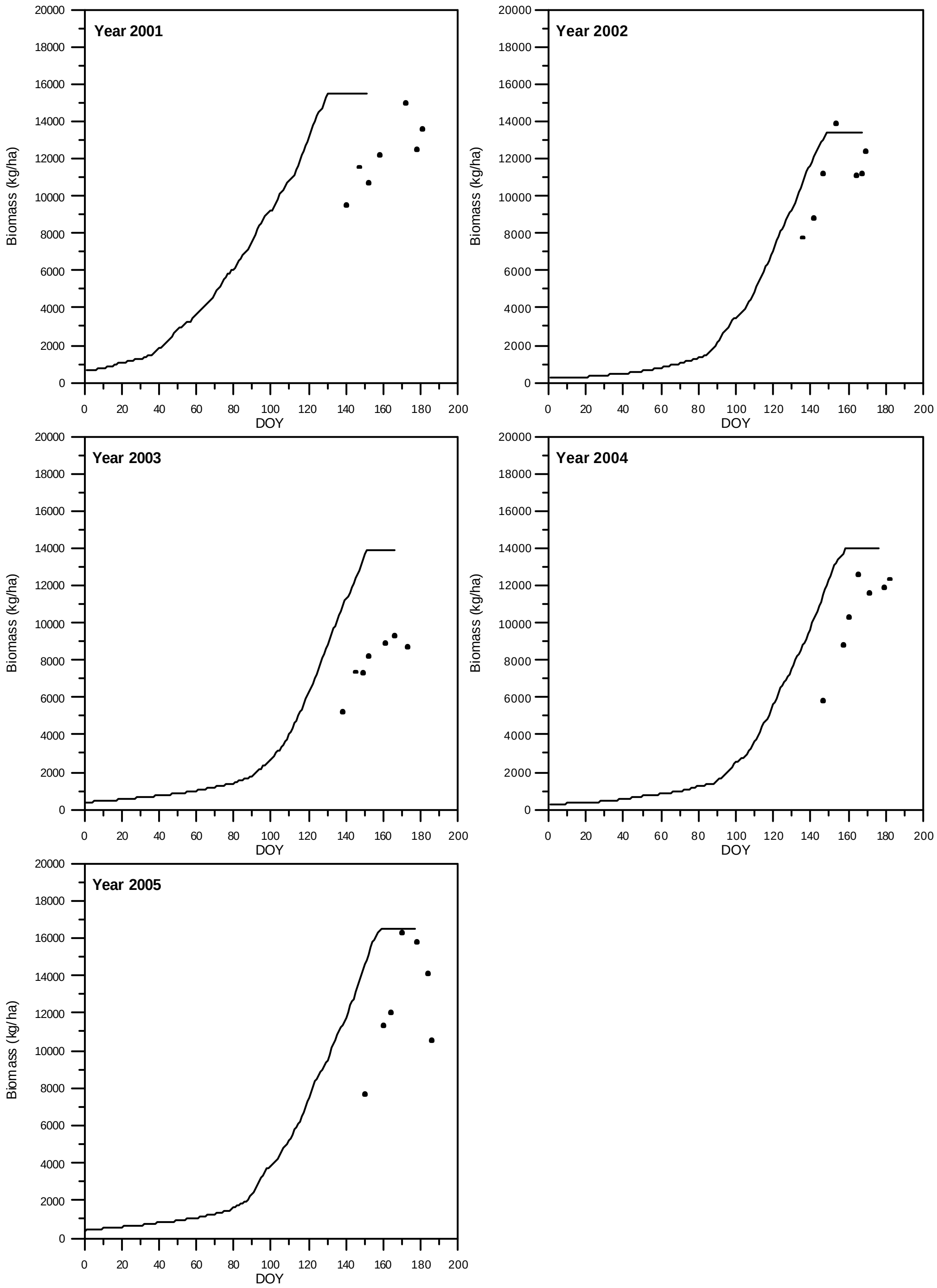

Figure 3 Biomass developments calculated using SIRIUS crop model for Anastasia winter wheat for 2001-2005 vegetation periods

However, deviation of simulated values decreases during vegetation period and causes rather small variation from observed biomass at maturity (Fig. 4).

(**Note:** In new version of SIRIUS were made some improvements related to these problems (Dr M. Semenov - personal communication). It is quite realistic to expect better results with new version of SIRIUS. Unfortunately I have no time to prepare it for this report)

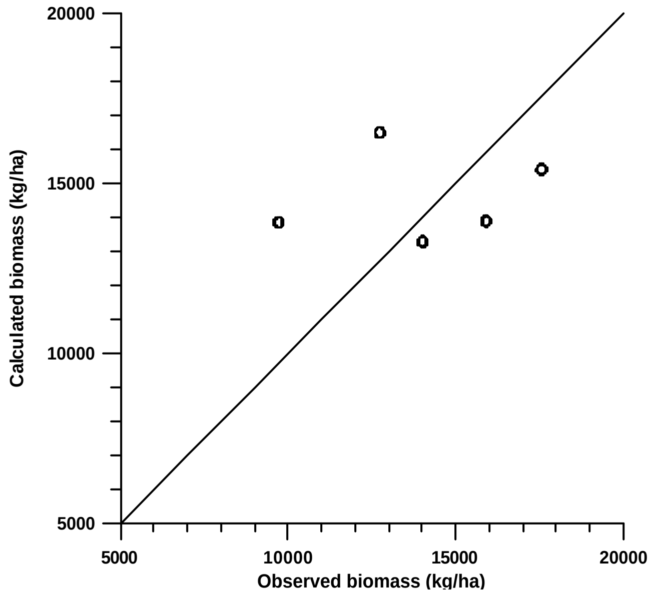

Figure 4 Comparison of biomass at maturity calculated using SIRIUS crop model and observed for winter wheat Anastazija during 2001-2005 vegetation periods

In contrast to biomass development, calculated timing and rate of grain yield development relatively good correspond to observed values while yield at maturity significantly deviates from observation (Fig. 5). Exception is year 2001 when, following SIRIUS, grain formation starts 20 days earlier. Described behaviour leads to significant deviation between observed and calculated yield at maturity (Fig. 6).

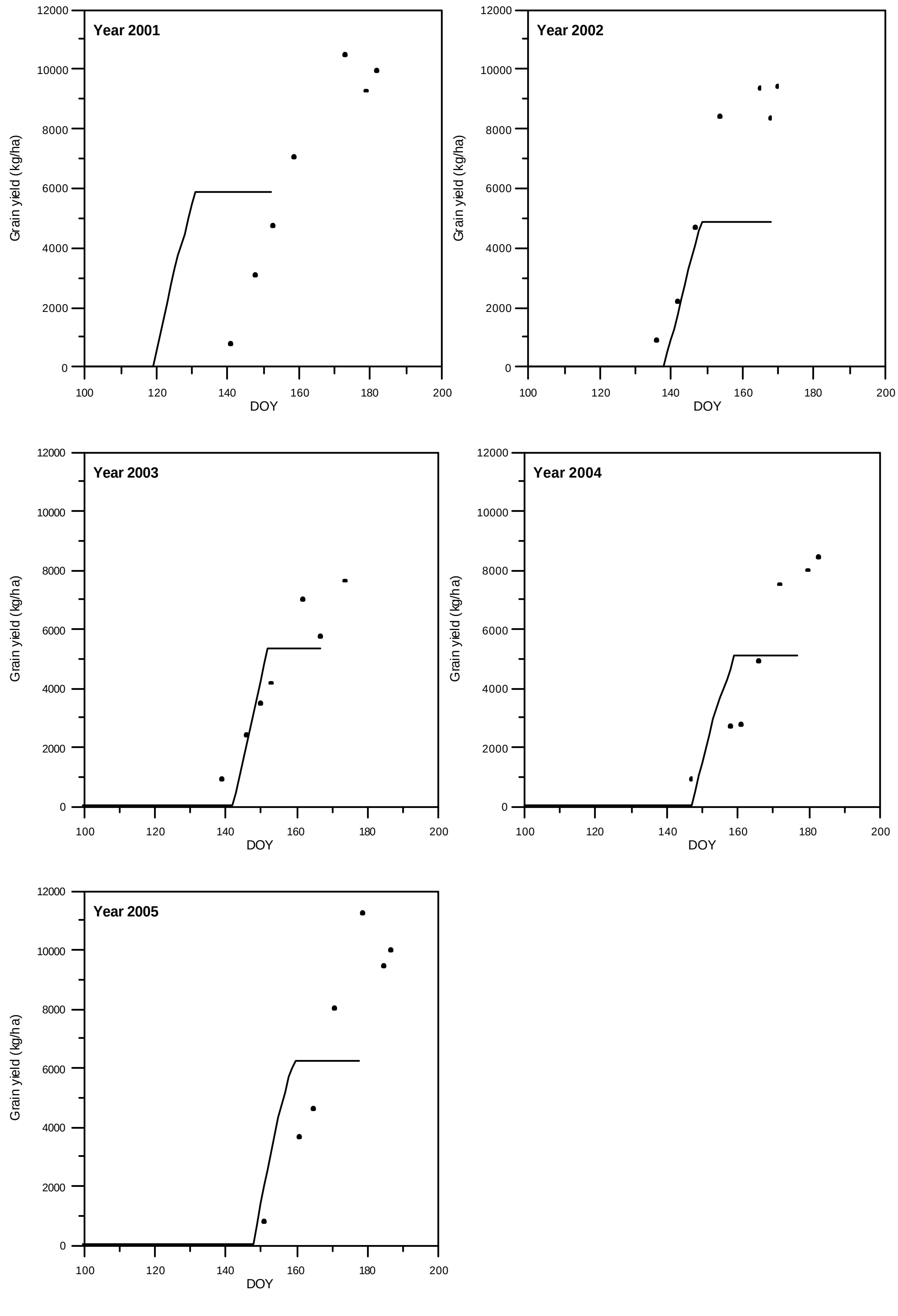

Figure 5 Grain yield development for Anastasia winter wheat for 2001-2005 vegetation periods

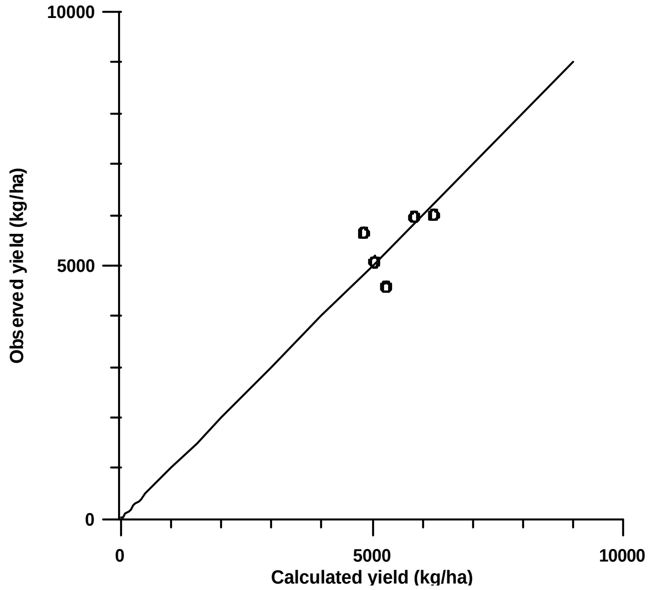

Figure 6 Comparison of grain yield at maturity calculated using SIRIUS crop model and observed for winter wheat Anastazija during 2001-2005 vegetation periods

Analysing above presented results one should have in mind that possible errors in observed data could be produced by non consistency in sampling and treating plants. From that point of view, one of wheat characteristics which could be determinate with

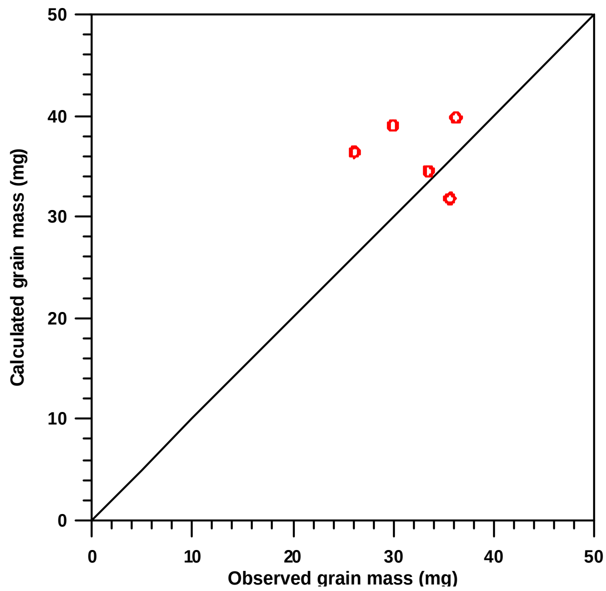

Figure 7 Comparison of grain mass at maturity calculated using SIRIUS crop model and observed for winter wheat Anastazija during 2001-2005 vegetation periods

highest accuracy is grain mass. Fortunately, in contrast to many other models, SIRIUS has advantage to calculate grain mass at maturity and gave information about single plant quality (Fig. 7). From Fig. 7 it is obvious that only for one year

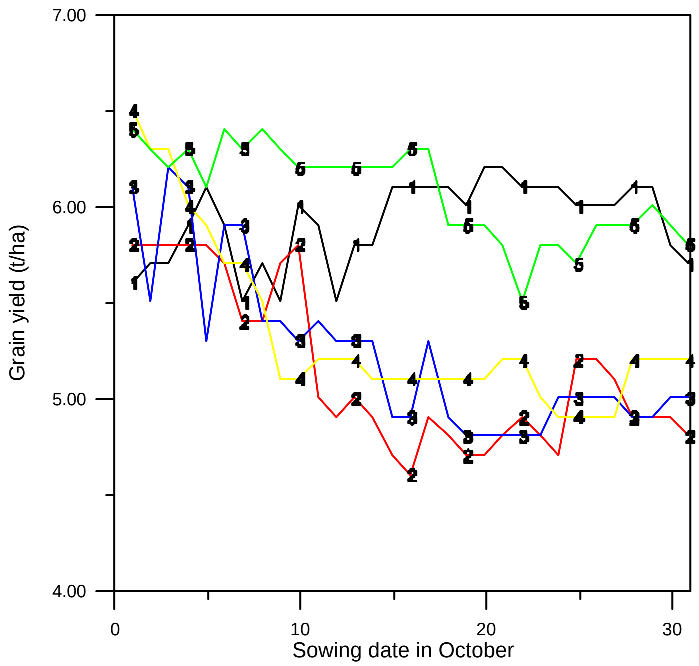

Figure 8 Sensitivity of grain yield to sowing date calculated using SIRIUS crop model for Anastasia winter wheat during 2001-2005 vegetation periods

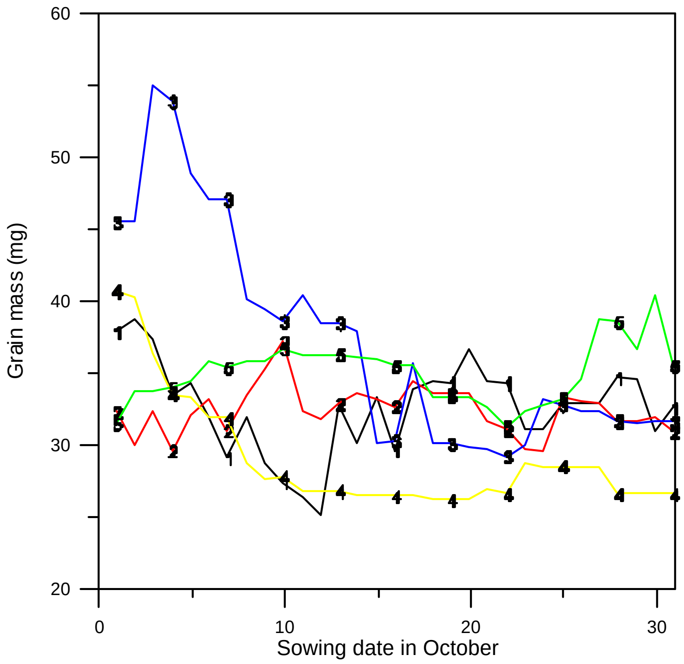

Figure 9 Sensitivity of grain mass to sowing date calculated using SIRIUS crop model for Anastasia winter wheat during 2001-2005 vegetation periods

(2004) there is a 10 mg (25%) difference between calculated and observed grain mass. In all other cases this difference is much smaller. Since SIRIUS exerted superiority in forecasting plant phenology dynamics it could be useful tool in forecasting the optimal sowing date related to grain yield (Fig. 8) and grain mass (Fig. 9). Not very detailed inspection of both figures leads us to conclusion that under observed conditions larger grain yield and mass could be achieved if sowing appears during first decade of October.

d.2) <u>Results of PERUN crop model calibration</u>

PERUN is a highly sophisticated crop model with numerous outputs. Unfortunately, in Serbian agricultural extension services and research institutes is not common practice to collect, on regular basis, all quantities comprised by PERUN outputs. Due to this reason, calibration and further validation of model outputs was reduced on growth stages, biomass and grain yield since grain mass is not one of calculated variables. Namely, PERUN is a crop model focused on canopy as a whole and not on single plant. In "phenology dynamic" part, PERUN calculates only emergence and anthesis apereance. From Fig. 10 is seen that calculated dates for emergence are accurate while there is a sistematic deviation of observed and anthesis dates calculated using PERUN crop model. It is rather obvous that PERUN is not best solution for phenology forecasting purposes.

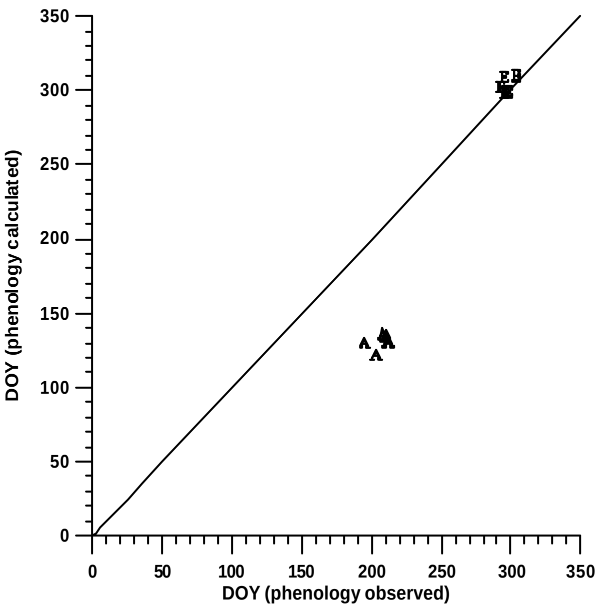

Figure 10 Comparison of dates of phenology phases calculated using PERUN crop model and observed for winter wheat Anastazija during 2001-2005 vegetation periods

Biomass and grain yield development was calculated for two extreme cases: a) potential crop production and b) water and O_2 limited production without ground water. Results achieved for Anastasia winter wheat are shown on Figs. 11 and 13.

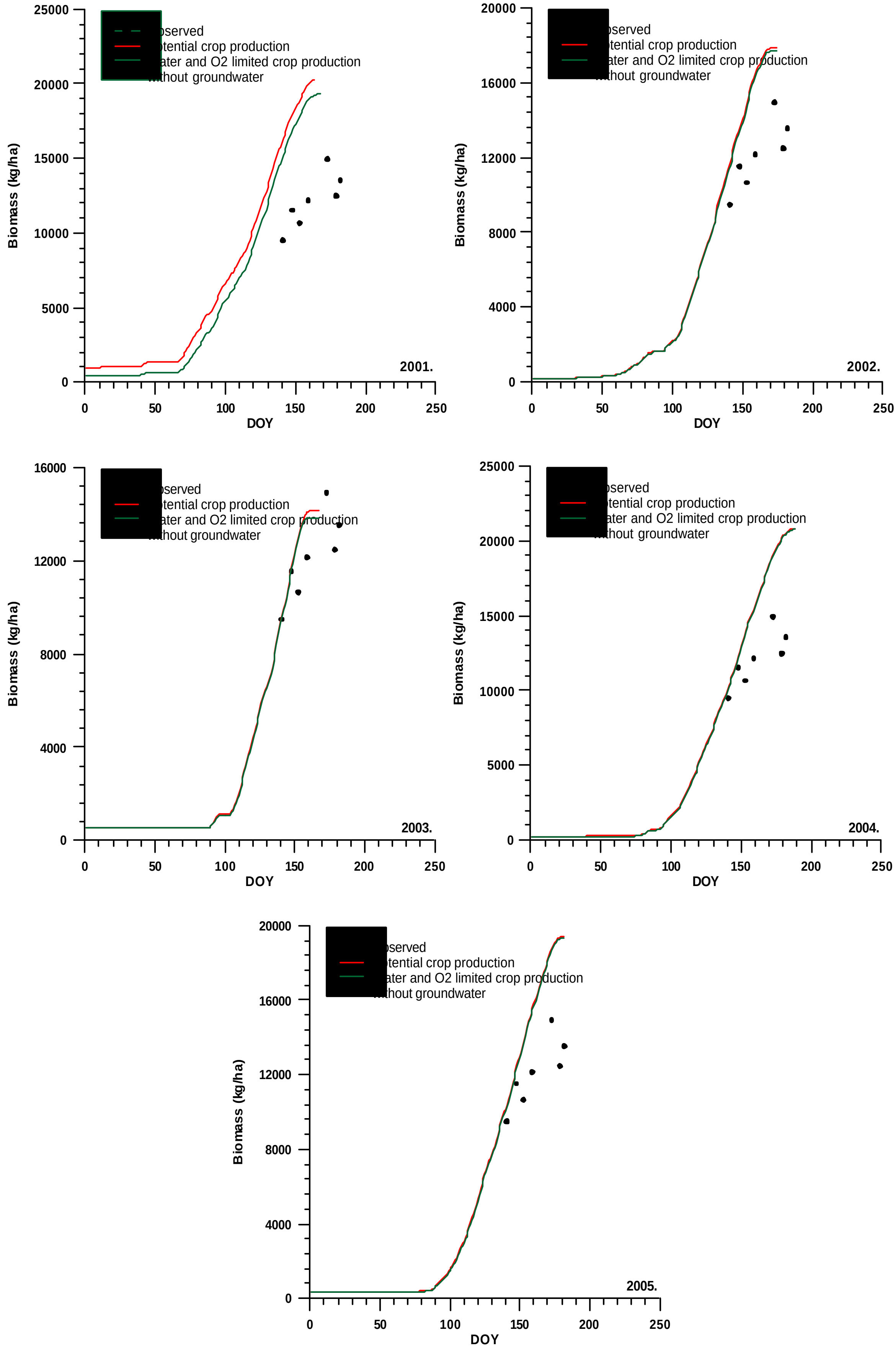

Figure 11 Biomass developments calculated using PERUN crop model for Anastasia winter wheat for 2001-2005 vegetation periods

Inspection of these figures indicates significant deviation between observed and calculated biomass and almost perfect correspondence in case of grain yield for all five vegetation periods. Comparison of biomass at maturity calculated under water and O_2 limited production with observed data (Fig. 12) shows systematic overestimation of calculated values in all cases. On the other hand, simulation of grain development during vegetation season is more accurate but maturity in the model happends much earlier than in realiy. It implies underestimation of calculated grain yield in comparison to observed values.

Taking into account all above mentioned results it seams as a best practical solution to use SIRIUS for phenology development forecasting and to improve calculation of grain yield and biomass for both SIRIUS and PERUN crop models.

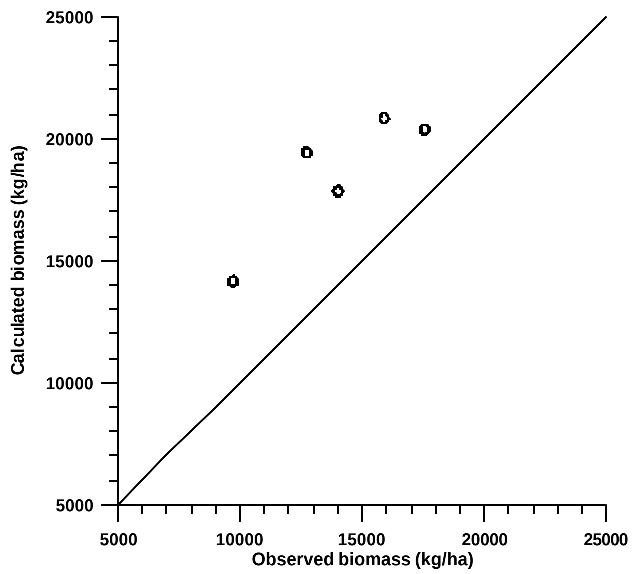

Figure 12 Comparison of biomass at maturity calculated using PERUN crop model and observed for winter wheat Anastazija during 2001-2005 vegetation periods

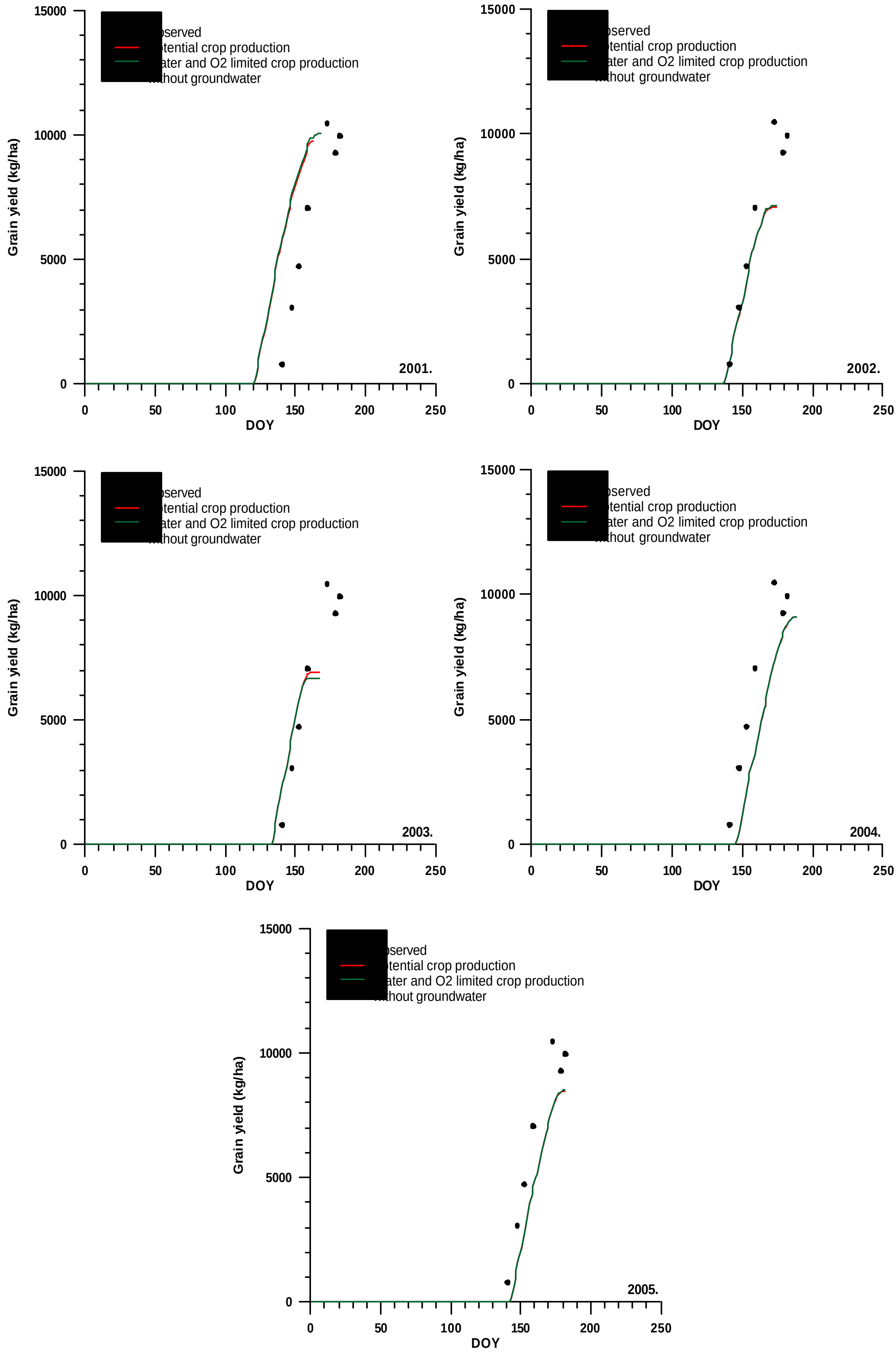

Figure 13 Grain yield development calculated using PERUN crop model for Anastasia winter wheat for 2001-2005 vegetation periods

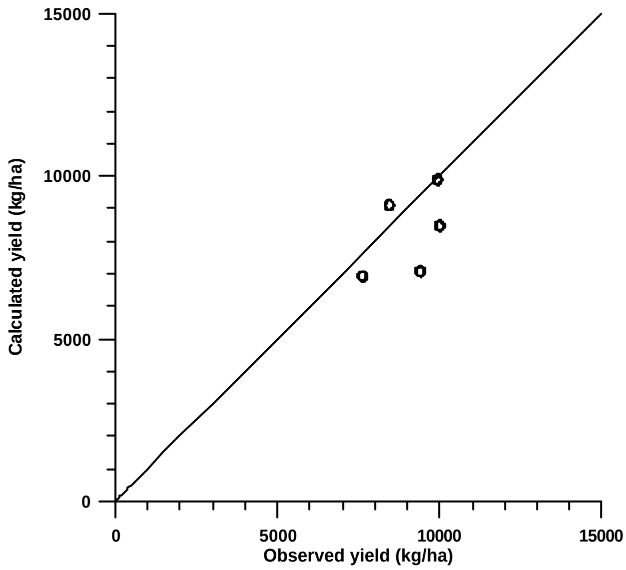

Figure 14 Comparison of grain yield at maturity calculated using PERUN crop model and observed for winter wheat Anastazija during 2001-2005 vegetation periods

Objective III - Application

Motivation: To provide actual and useful information for farmers related to planting, management and protection of their crops.
Activities: Improvement of farm operations management timing. For farmers, it is essential to know in advance when and what should be done. Since most crop models are diagnostic one, all predictions should be based on weather forecasting or weather scenarios depending on methodology and time scales.
IN REALISTIC CASE THIS PART OF PROJECT SHOULD BE CARRIED OUT FOR NEXT SEASON OF WINTER WHEAT, I.E., SINCE OCTOBER 2006.
Users: Agricultural advisory services; farmers; producers of seed and pesticides; decision makers
Communication: Transfer of information to users will be provided on following way: a) through the media b) seminars for producers organised on national level and d) using network of clients (farmers) of Institute for field and vegetable crops from Novi Sad. Namely, my Department has special contract of cooperation with this institution, which is well known producer of field and vegetable crop seed, providing complete consulting for farmers concerning crop management. On this way we can provide communication short-cut to producers.

Realisation:

On the basis of all above presented results it is rather obvious that SIRIUS crop model could be used for phenology dynamic forecasting and, on that way, improvement of farm management operation practices. Problem is that SIRIUS is a diagnostic model and that it efficiency in phenology forecasting is strongly dependant on accuracy of weather data during the vegetation period. On the other hand, even data series indicated in Tab. 1 represent synthetic weather there is a possibility to use generated weather as a crop model input. To check ability of generated data, to be a trustful source of input data for a crop model, one data serie for year 2005th was selected. SIRIUS crop model was run using observed and generated weather data and following results are obtained

Sirius 2005 OUTPUT FILE

Weather	**Observed**
Site	Rimski
Variety	ANASTASIJA
Soil	Chernozem

Sowing Date 19/10/2003

Sowing	292	19/10
Emergence	311	7/11
Anthesis	143	23/5
Begin Grain Fill	149	29/5
End Grain Fill	161	10/6
Maturity	178	27/6

Final Leaf Number 11.10

Anthesis Biom,kg/ha	10389
Biomass, kg/ha	13883
Grain, kg/ha	5052

Crop N, kg/ha	336
Grain weight, mg	26.12
Grain N, %	3.55

Sirius 2005 OUTPUT FILE

Weather	**Generated**
Site	Rimski
Variety	ANASTASIJA
Soil	Chernozem

Sowing Date 19/10/2003

Sowing	292	19/10
Emergence	311	7/11
Anthesis	139	19/5
Begin Grain Fill	144	24/5
End Grain Fill	156	5/6
Maturity	176	25/6

Final Leaf Number 11.26

Anthesis Biom,kg/ha	9881
Biomass, kg/ha	12974
Grain, kg/ha	5013

Crop N, kg/ha	323
Grain weight, mg	33.52
Grain N, %	3.36

After comparison of SIRIUS outputs obtained using observed and generated weather data one can make following conclusions:

a) maximum deviation in phenology dynamic is obtained for begin and end of grain fill – 5 days
b) deviation of biomass at anthesis is 5%
c) deviation of biomass at maturity is 6.5%
d) deviation of grain yield at maturity is 0.8%
e) deviation of grain mass at maturity is 28 %

Obviously, except in case of grain mass, all results obtained using generated data correspond to outputs obtained using observed weather data.

Obtained results will be submitted for presentation on traditional winter seminar for producers organised on national level and local media as well as during direct communication with producers.

References

1. Mahfouf, J.F., 1990: A numerical study of the surface water budget during HAPEX- MOBILHY. *Boundary-Layer Meteorol.*, 53, 201-222.
2. Mihailovic, D. T., and F. Acs, 1985: Calculation of daily amount of global radiation in Novi Sad. *Idojaras*, 5, 257-261.
3. Mihailovic, D.T., T.J. Lee, R.A. Pielke, B. Lalic, I. Arsenic, B. Rajkovic, P.L. Vidale, 2000: Comparison of different boundary layer schemes using single point micrometeorological field data. *Theor. App. Climatol*., 67, 135-151.
4. Pielke, P.A., 1984. *Mesoscale meteorological modelling*. Academic Press, New York, 612 pp.