Essential Variables estimation with use of biophysical WOFOST model in the context of GEO-Essential project

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Essential Variables approach

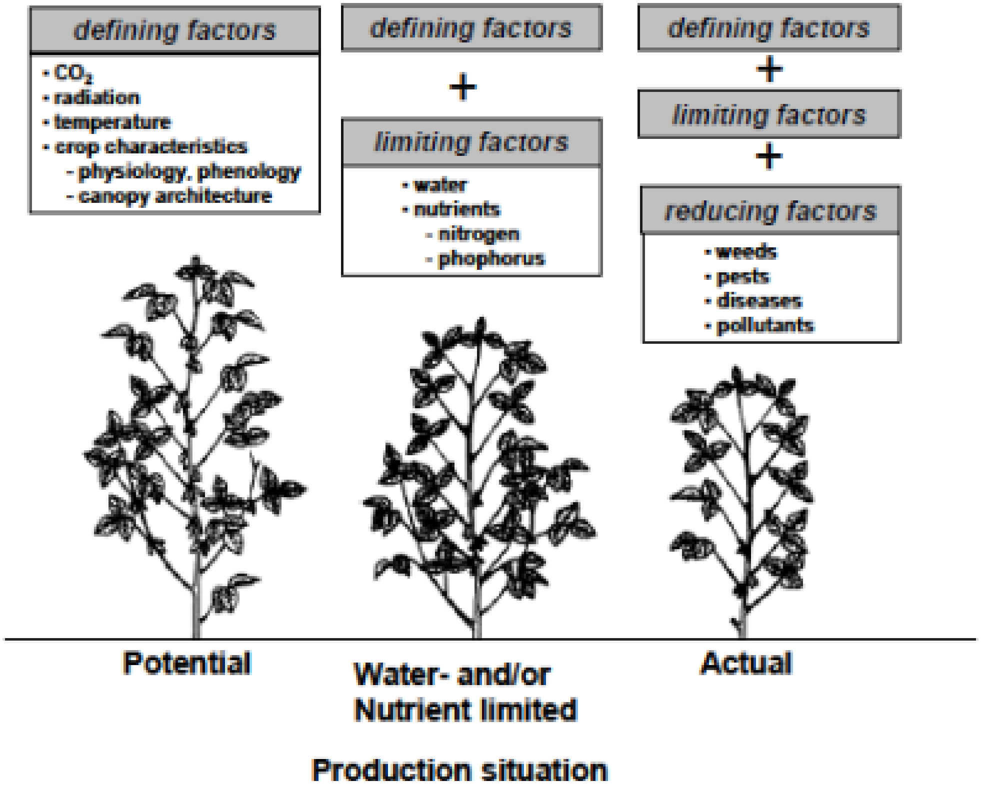
The Essential Variables approach to monitoring complex systems The concept of Essential Variables was first used by the Global Climate Observing System (GCOS) in the 1990s. It defined essential climate variables (ECVs) as “physical, chemical, or biological variables or a group of linked variables that critically contributes to the characterization of Earth’s climate” (GCOS 2010). The ECVs were proposed as a response to the need for a more coordinated approach to global climate observations (Belinda Reyers et al, 2017).

Subtask 6.2.5 EVs for agricultural monitoring

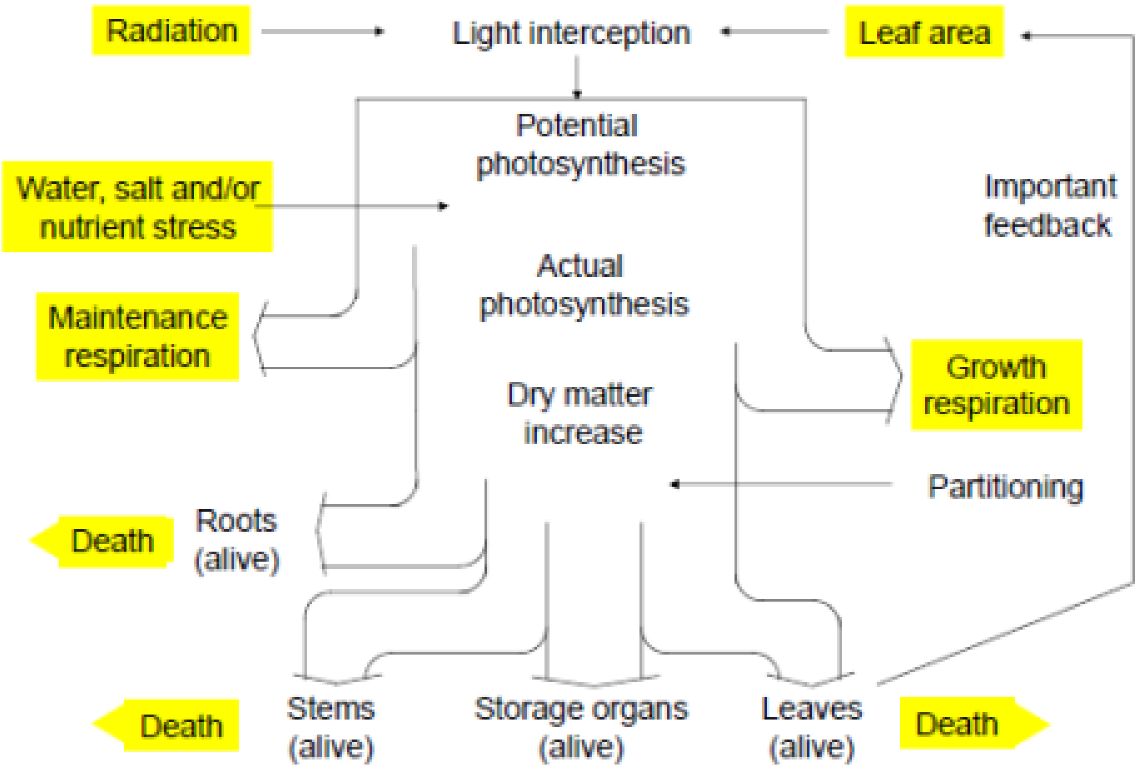
Monitoring of essential environmental variables (e.g. LAI) and essential agricultural variables

WOFOST model

The WOFOST (WOrld FOod STudies) is a simulation model for the quantitative analysis of the growth and production of annual field crops. It is a mechanistic model that explains crop growth on the basis of the underlying processes, such as photosynthesis, respiration and how these processes are influenced by environmental conditions crop growth processes at three different levels.

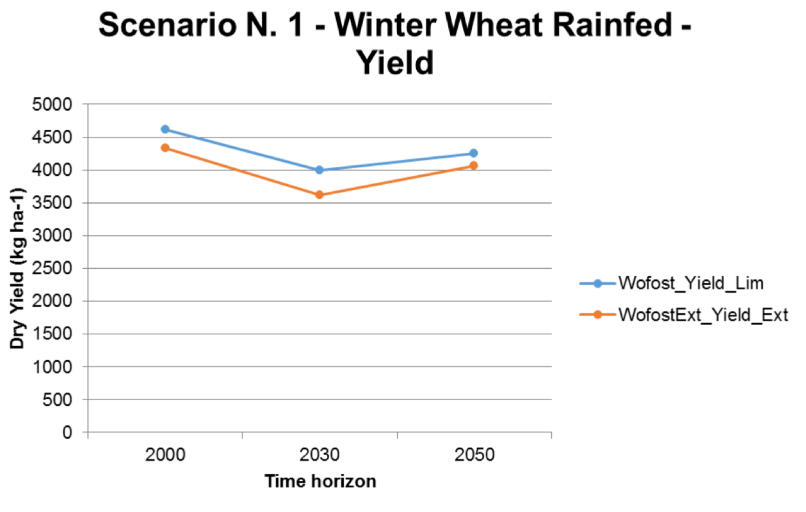


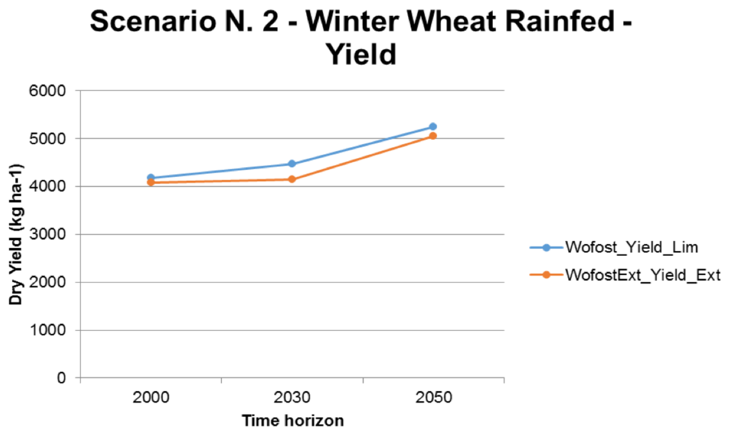
(Van Ittersum et al., 2003).

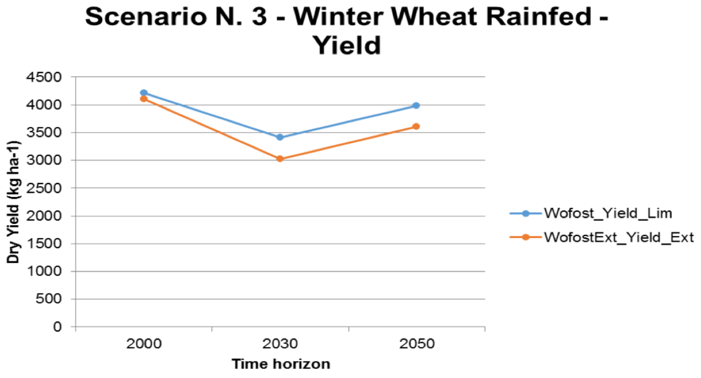


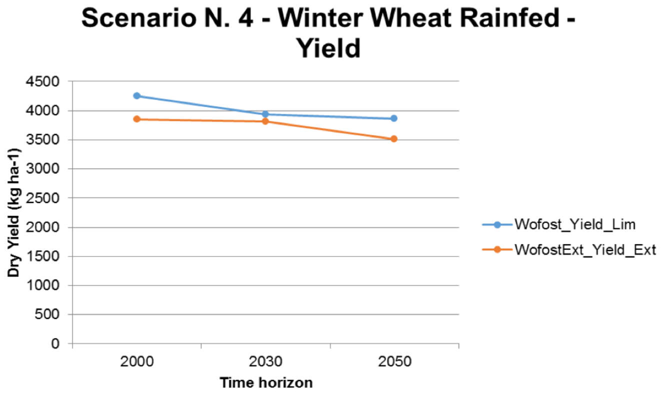
Overview of crop growth processes incorporated in WOFOST

MODEXTREME Project. Winter wheat

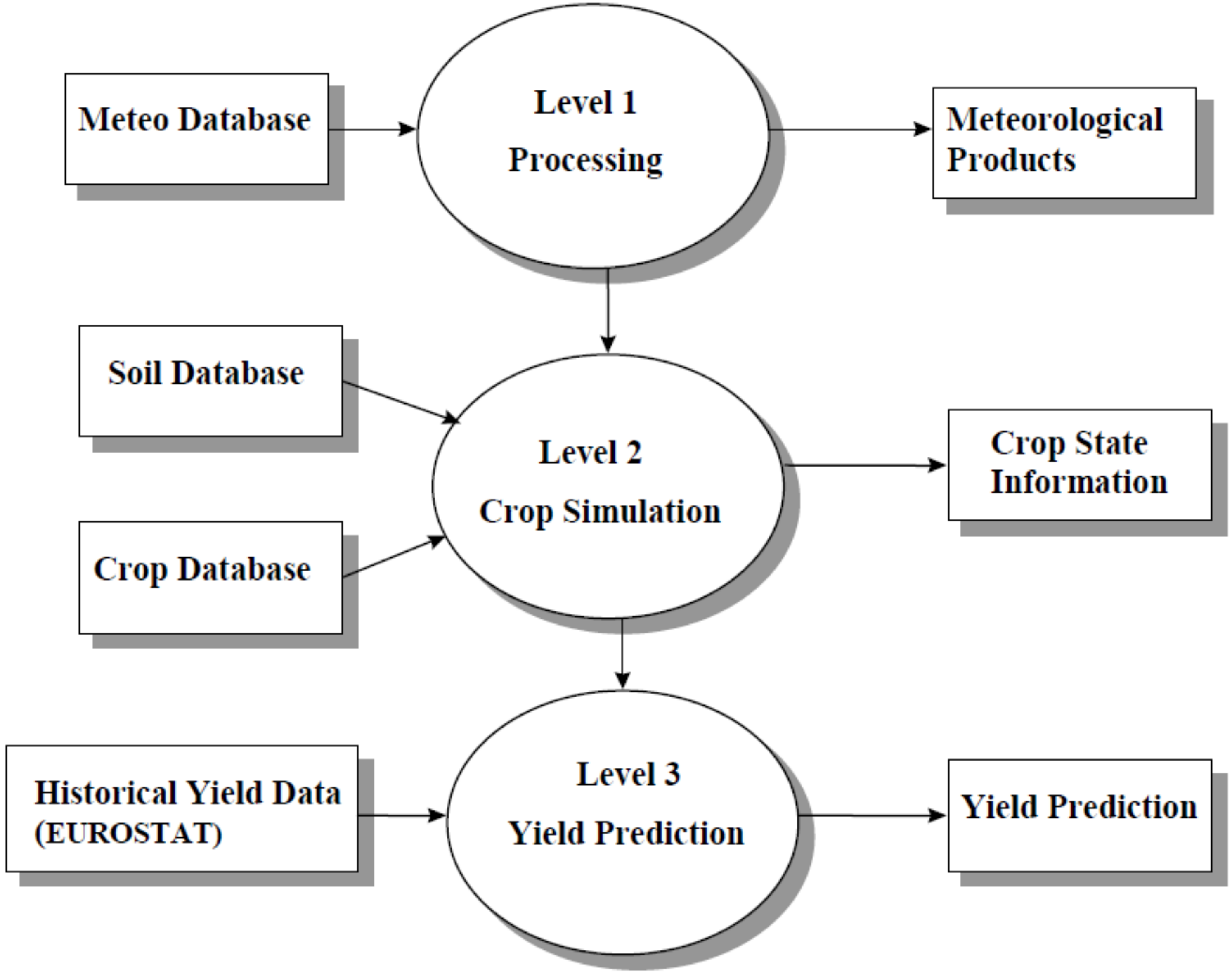








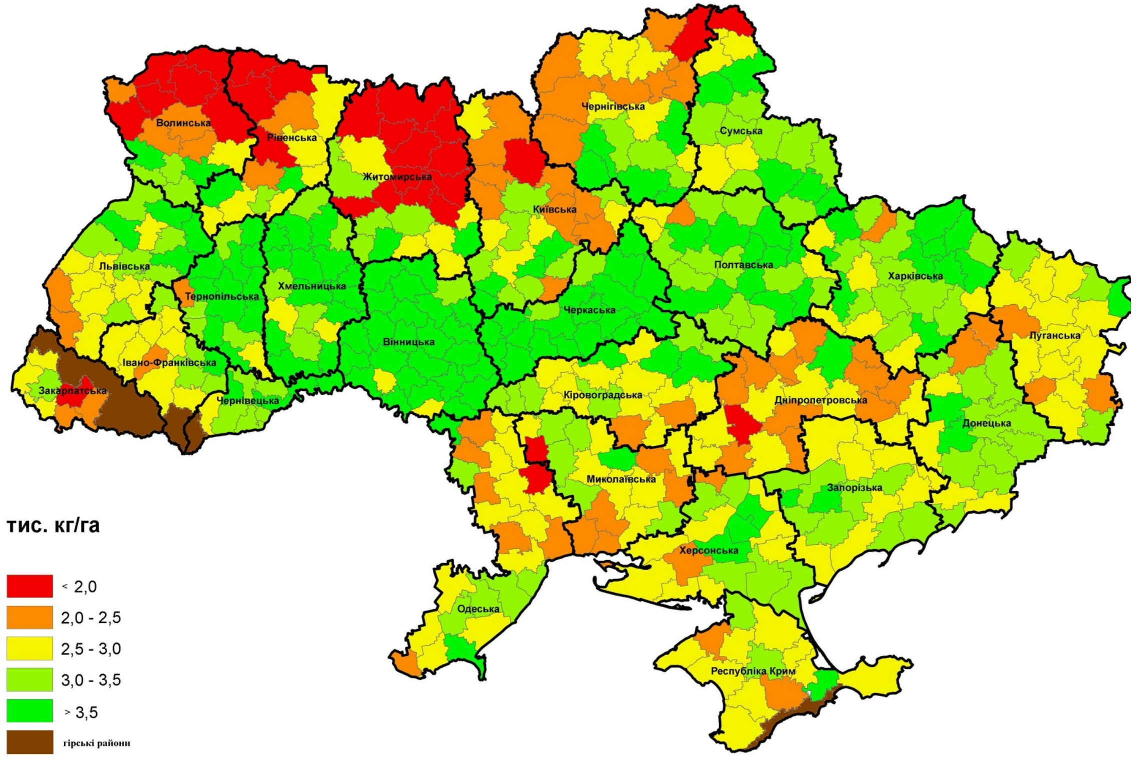
CGMS-Ukraine
(http://entln.uhmi.org.ua/case/CGMS/)



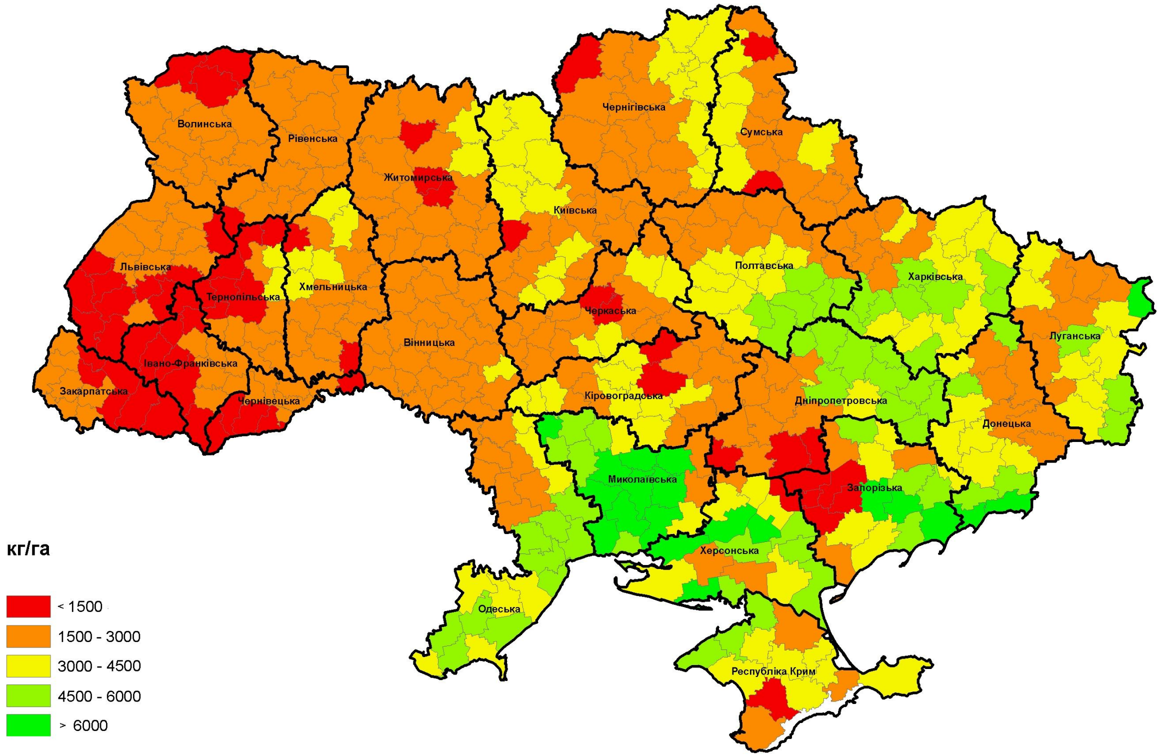
Forecasted Crop Yield

Water Limited Biomass

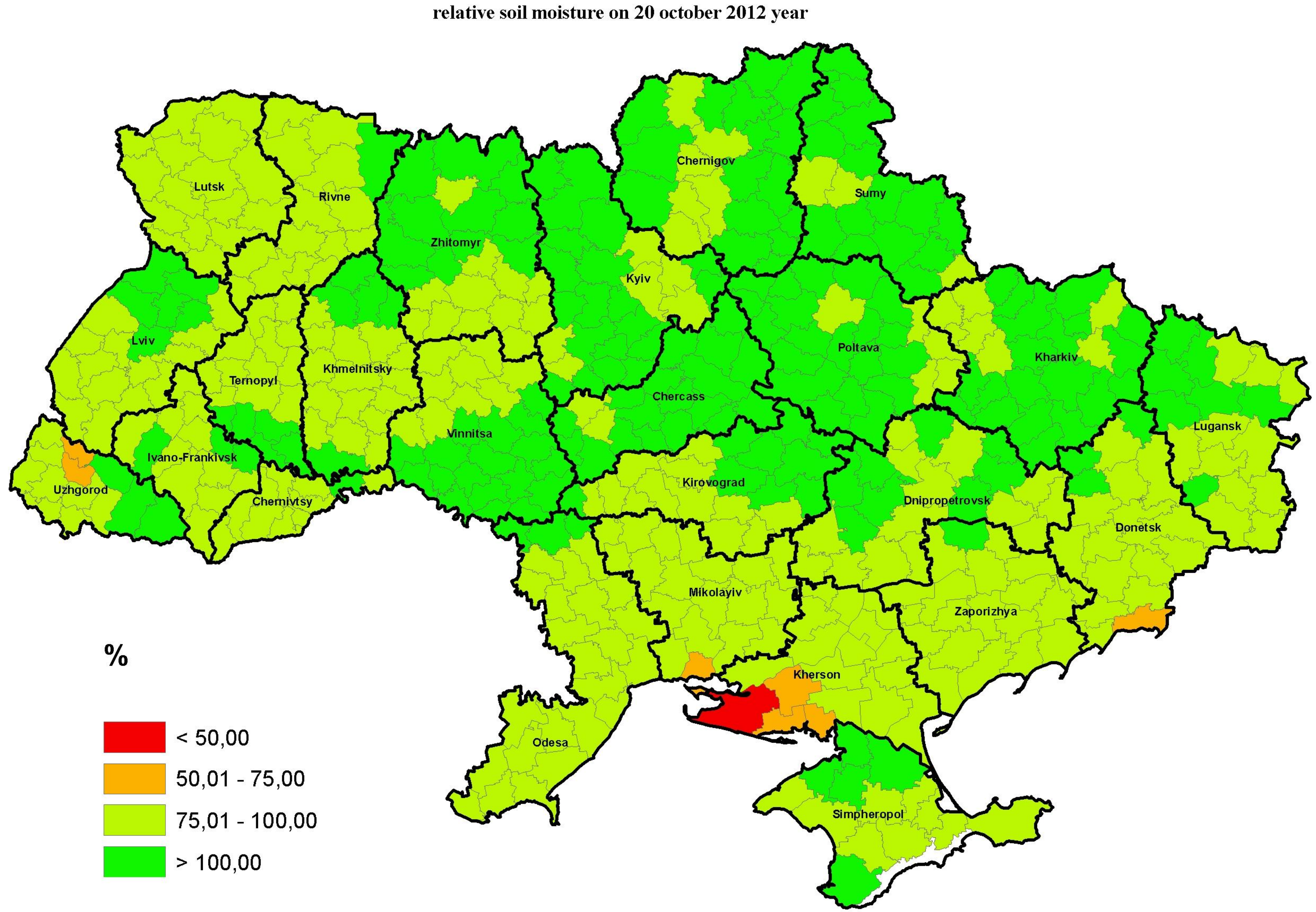
Прогнозна урожайність озимої пшениці на 30 квітня 2012 року



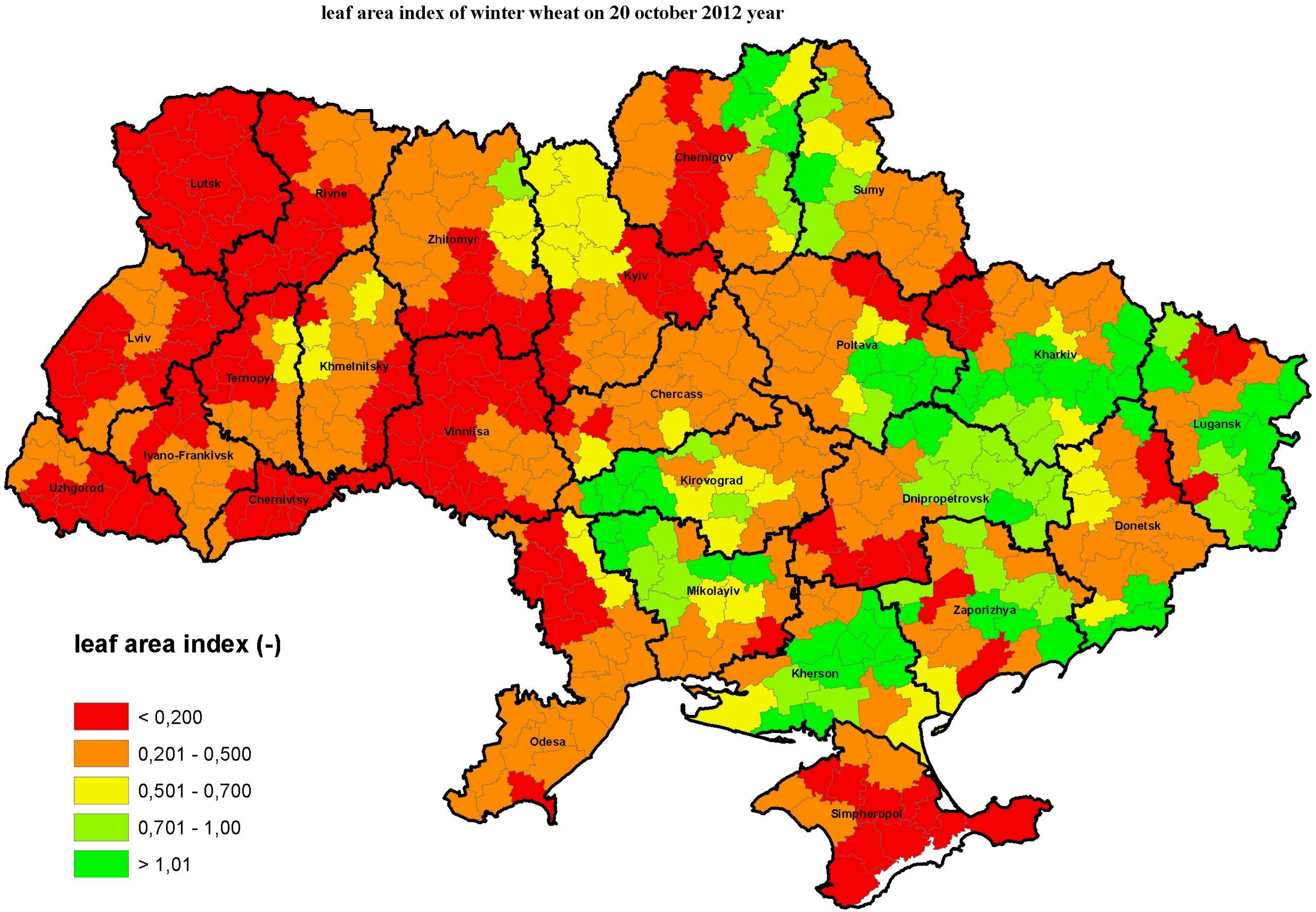
Кількість біомаси озимої пшениці при недостатньому зволоженні на 30 квітня 2012 року



Soil Moisture

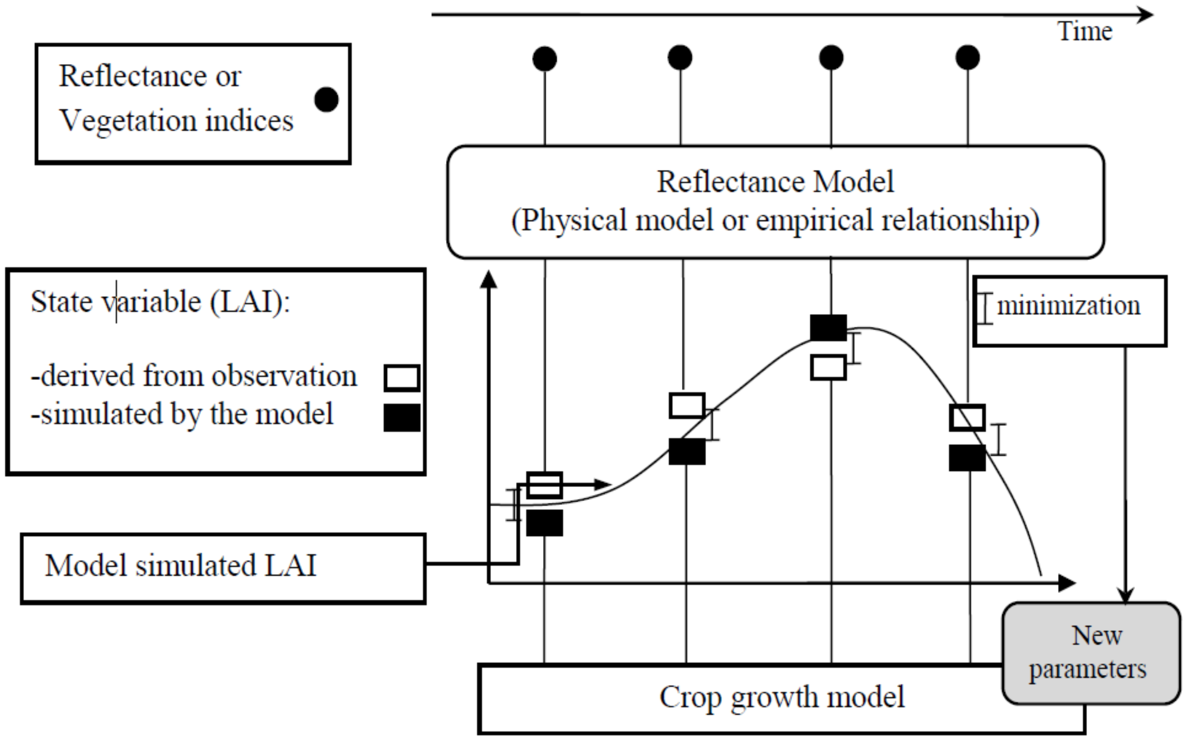


LAI


leaf area index of winter wheat on 20 october 2012 year
Lutsk
Rivne
Zhitomyr
Chernigov
Sumy
Kyiv
Lviv
Ternopyl
Khmelnitsky
Poltava
Kharkiv
Lugansk
Chercass
Vinnitsa
Ivano-Frankivsk
Uzhgorod
Chernivtsy
Kirovograd
Dnipropetrovsk
Donetsk
Mikolayiv
Zaporizhya
Kherson
Odesa
Simpheropol
leaf area index (-)
< 0,200
0,201 - 0,500
0,501 - 0,700
0,701 - 1,00
> 1,01

Strategy for optimizing crop growth models

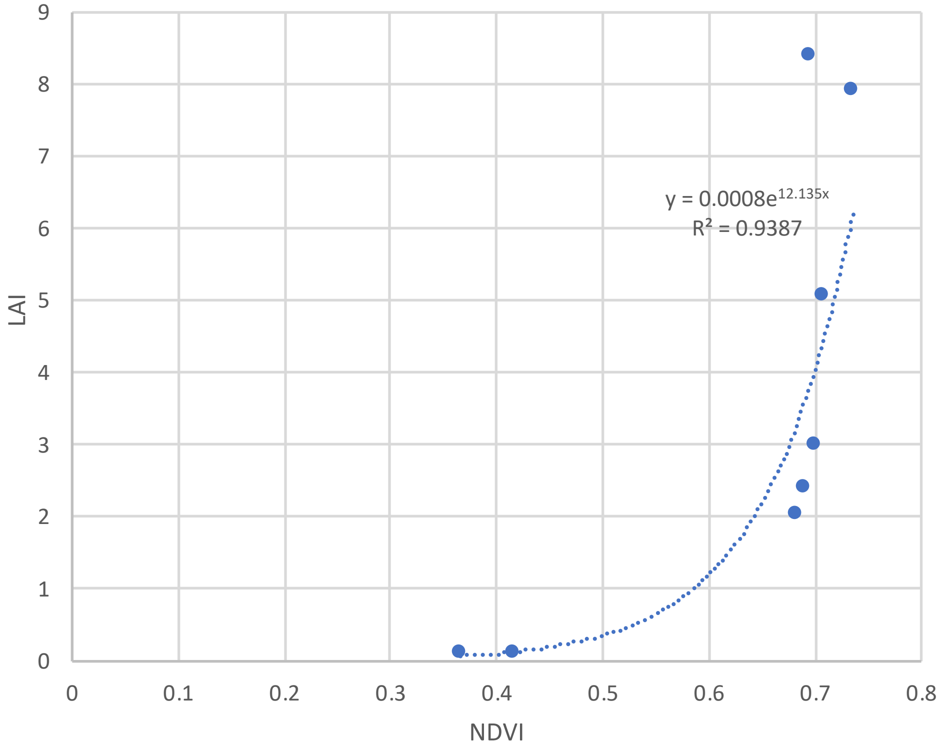
Crop growth models have some flaws on optimizing the agricultural production and growth process. Crop growth models cannot obtain effects of disasters and pest on canopy growth status of crop. Additionally, crop growth models can not accurately simulate the agricultural production on a regional scale. However, remote sensing can capture the timely canopy information of crop to provide true observations of winter wheat growth status on a regional scale.



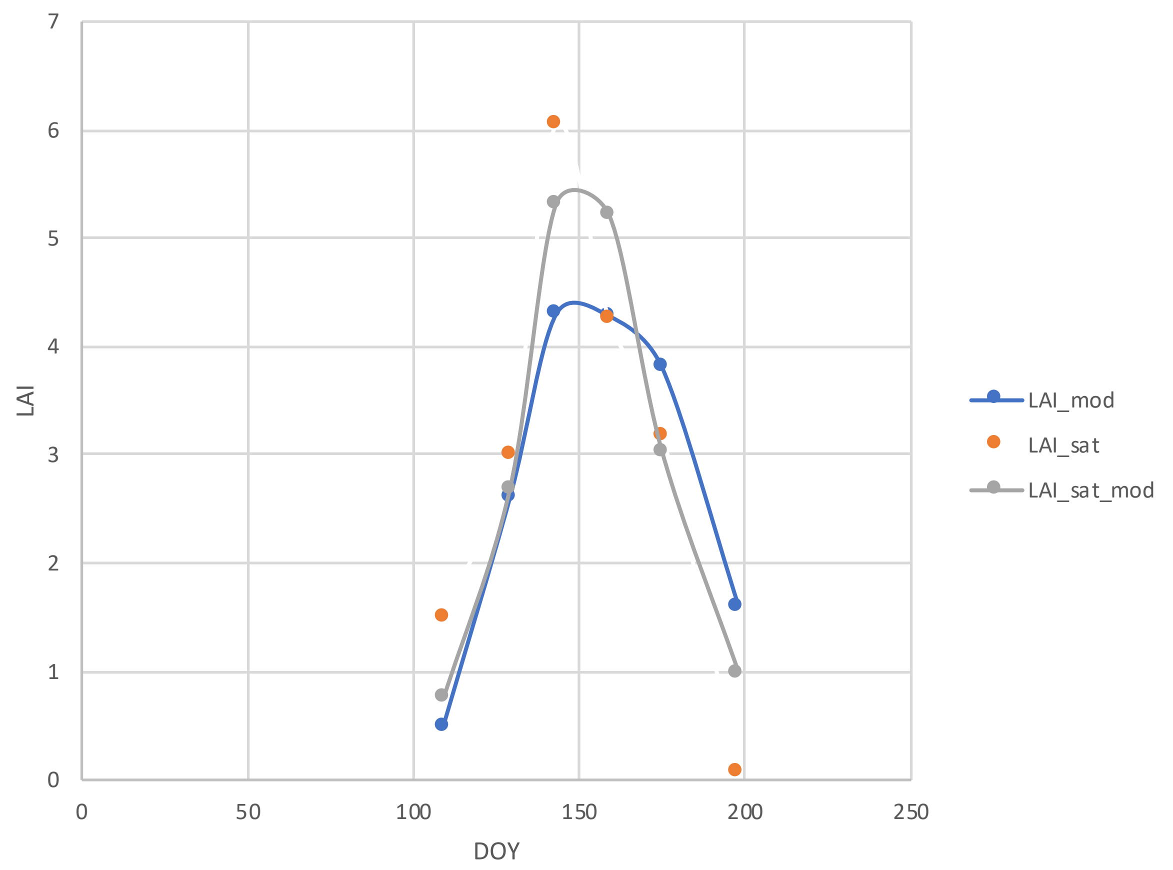
(Delécolle et al., 1992)

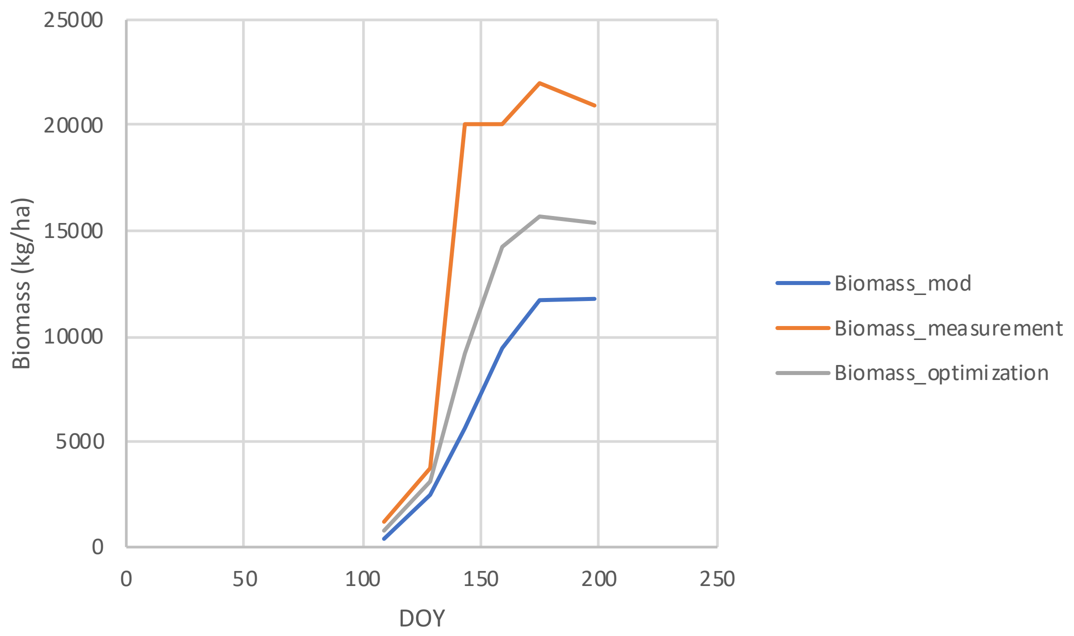
LAI retrieval from Landsat 8 OLI images

To obtain the regional LAI maps within a growth period of crop, the relationship between the observed LAI and corresponding vegetation index derived from remote sensing images was modelled. In this relationship, the vegetation index NDVI derived as a composition of visible, near infrared red bands, is used. The relationship between the observed LAI and vegetation indices derived from remote sensing images was limited to the canopy closure and soil reflectance (**Peddle et al., 1999**). In the study, the soil background noise in winter wheat fields is limited with vegetation closure at the middle growth stage affects the accurate extraction of vegetation index. The relationship between NDVI and LAI is shown on Fig.2.



Relationship between NDVI and LAI of winter wheat crops





The matching between the observed and simulated yield winter wheat fields using the WOFOST model

The matching between remote sensing derived LAI and initial LAI using WOFOST model, simulated LAI after the assimilation at targeted winter wheat crops.
LAI_mod – initial WOFOST simulated LAI;
LAI_sat – remote sensing observed LAI;
LAI_sat_mod – simulated LAI assimilated satellite data

Tab.1. Storage biomass (kg/ha) simulated(forecasted) by WOFOST, initial, optimization modes and estimated on the field.

Field measurements	WOFOST optimization	WOFOST initial
5820	4976	4289
10760	7833	6383

Agro-pheno and meteorological ground network of UHC

Meteorological ground network - 186 meteorological stations;
Agro-meteorological ground network - 163 agrometeorologcal sites.

Crop, vegetation phase	Parameter	Description	units
1	2	3	4
Winter wheat			
Soil moisture per decade (in autumn after harvest up to late autumn; in spring – in the beginning of vegetation up to maturity)	available water content (AWC) in layers	0-10 cm, 0-20 cm, 0-50 cm, 0-100 cm	mm
Sowing	Date		
Germination	Date		
Emergence	Date	> 50% of plants(visual analysis)	
	Crop assessment	1-5(visual analysis)	
Formation of root node	Date		
	Crop assessment	1-5	
3-d leaf	Date	> 50% of plants	
	Crop assessment	1-5	

Conclusions:

1. WOFOST model produces realistic biophysical parameters of different crops and can be used for estimation of EV

2. The assimilation results on a field scale based on the optimization algorithm show that this assimilation strategy is better than the mono WOFOST model simulation. The coupling model between remote sensing and WOFOST model proposed in this research can effectively resolve the limitation upscaling the crop growth model simulation from a field scale to a regional scale.

3. Agrometeorological network of Ukrainian Hydrometeorological Center can provide additional information of a crops state for satellite data interpretation