



EUROPEAN  
COMMISSION  
**Horizon 2020**  
EUROPEAN UNION FUNDING  
FOR RESEARCH & INNOVATION



**Serbia for Excell**  
H2020 - TWINN - 2015

**A<sub>g</sub>M<sub>net</sub><sup>+</sup> INTERNATIONAL**  
**SUMMER SCHOOL**  
**IN AGROMETEOROLOGY AND CROP MODELLING**

**10 July - 14 July, 2017**  
NOVI SAD, SERBIA

**BOOK OF ABSTRACTS**



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## **Challenges in agrometeorological research and application**

**Rene GOMMES**

**Senior agrometeorologist consultant**

Agrometeorology is often described as a “hybrid” science. Even if most universities will offer training and degrees that qualify as “agrometeorology”, few will actually award formal degrees in the subject. “Agrometeorology”, like “climate change impact” belongs to and into many technical fields that span the spectrum from environmental physics to plant protection and animal health, crop geography and remote sensing, crop production and irrigation techniques, even bordering on history (e.g. reconstruction of yield series) and socio-economics (forecasting crop prices). As a result of the vastness of the subject, operational agrometeorologists are often confronted with gaps in knowledge, tools and data, some of which are surprising when considering the current level of sophistication of much “agrometeorological” research. By necessity, the presentation focuses on some typical examples of global (rather than local) relevance, starting with the lack of any modern climate classification for agriculture. There is, obviously, a link between crop geography and the many variants of post-Köppen climate maps, but none of them incorporates the simple fact that crops can grow over just a few months, so that winter or dry season temperature conditions are basically irrelevant for summer/rainy season grown crops. Other examples refer to the irrigation potential or inter- and intra-seasonal variability, two essential components of crop-climate relations that are not captured by existing climate maps. A related subject is the global distribution of crop types together with their phenology (including the variability) , which must incorporate remotely sensed and ground data, agroclimatic indicators, soil factors etc. Various attempts exist to tackle those issues, but all international crop monitoring exercises are confronted with the same lack of basic information about actual crop distribution. The last point which the presentation focuses on is simple crop models: there is a lack of models that are adapted to real-world conditions of limited data availability at the adequate scale. Such models should ideally be sufficiently “process-oriented” to describe plant-soil-climate-management interactions sufficiently well, but refrain from requiring inputs that users have to guess. Such models could also use standard remotely-sensed inputs such as Normalised Difference Vegetation Indices (NDVI) to derive Leaf Area Indices (LAI) or phenology. Some additional “challenges” are mentioned and could form the basis for collaborative projects.

## **Application of crop models in tactical and strategic decision-making in farming systems**

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### ***APSIM Training Course at Novi Sad University***

The (Agricultural Production Systems sIMulator (APSIM) is internationally recognised as one of the most advanced and comprehensive crop/cropping system models for simulating the effects of genetic factors, environmental variables, and management decisions on production (crops, pasture, trees, livestock), profits, and the environmental variables (e.g. soil erosion, nitrate leaching) (<http://www.apsim.info/>).

APSIM incorporates a generic crop model, which utilises a library of routines for simulating growth and development processes for more than 20 crop species. Environment modules of APSIM handle variables such as climate and weather, soil characteristics (e.g. water balance, nutrients, pH, temperature), crop residue, and erosion. The Management modules allow management rules for a given scenario to be specified, including variables related to crop sowing, harvesting, fallowing, tillage, irrigation, fertiliser use, grazing management, stocking rate, and intercropping. APSIM has been used in a broad range of applications including supporting on-farm decision making, designing farming systems for production or resource-management objectives, guiding crop breeding strategies, assessing risk for government policymaking, and evaluating management options for adaptation to climate change and variability.

This course is aimed at providing training in the use of APSIM. It is very 'hands on' with a mix of short presentations and tutorials. The lecture programme includes the following topics:

APSIM User Interface:

- How to build, run, and graph a simulation
- Principals of modelling crop growth and development
- Modelling plant available soil water content
- Modelling nitrogen dynamics – Soil nitrogen availability and plant uptake

## **Modeling intercrops: overview of models and approaches**

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Current cropping systems in Europe are characterized by high productivity but rely on simplification of crop rotations and high level of chemical/synthetic inputs which has led to soil, water and air pollution and loss of biodiversity (e.g. Stoate et al., 2009). Aiming at higher crop diversity, intercropping is an interesting option to improve agronomic, economic and environmental performance. It is defined as the simultaneous growth of two or more species in the same field for a significant period of time (Willey 1979a) but without necessarily sowing or harvesting at the same time (Vandermeer et al. 1998; Malézieux et al. 2009).

Niggli et al. (2009) describe intercropping as an eco-functional intensification practice which has been widely used to boost crop productivity (Qin et al. 2013), increase the land utilization ratio (Agegnehu et al. 2008) and emit significantly lower amounts of greenhouse gases compared to sole crops (e.g. Oelhermann et al. 2009; Naudin et al. 2014). The cereal-legume interactions based on functional complementarity could then be a more suitable way to improve and stabilize yields (Hauggaard-Nielsen et al. 2009b; Lithourgidis et al. 2006) and also to increase the cereal grain protein concentration as compared to the respective sole crops (Gooding et al. 2007) particularly in low-N-input systems (Hauggaard-Nielsen et al. 2003; Bedoussac and Justes 2010a, 2010b). Intercropping has also been shown to: (i) improve soil conservation (Anil et al. 1998), (ii) favour weed control (Banik et al. 2006; Corre-Hellou et al. 2011), (iii) reduce pests and diseases (Altieri 1999; Corre-Hellou and Crozat 2005; Ratnadass et al. 2012) and (iv) provide better lodging resistance (Anil et al. 1998).

In order to evaluate their suitability, innovative cropping systems including grain legumes need to be carefully assessed using a diversity of performance indicators: e.g. provision of ecosystem services, economic performance, and stability in the face of climatic and abiotic factors variability. Traditional factorial experimental approaches are then limited also

because of the numerous combinations between species, environments and practices (Malézieux et al. 2009). Therefore, models are useful tools to help this assessment and allow to: (i) estimate indicators that are tedious or expensive to quantify in experimental plots, e.g. water drainage, N<sub>2</sub>O emissions or N leaching and (ii) explore the robustness of innovative cropping system for a wide range of environmental conditions (soil conditions, various weather sequences and different management schemes) that modify the yield and environmental impact of intercropping systems.

However, the modelling tools widely used today in agronomy are not always well adapted to simulating intercropping systems. Nevertheless, models have been developed or adapted to represent, assess and design sustainable intercropping systems. As indicated previously by Malézieux et al. (2009), “*models have not been designed for the same purpose, or for the same users, and a comparison is therefore tricky*”. Indeed, they often combine simplicity and complexity: one could be very simple concerning one mechanism, while being more realistic and close to mechanistic models for other processes. In my presentation I will describe different models in order to highlight different ways of simulating multispecies cropping systems with models.

## **Agrometeorological measurements and application**

### **“Evapotranspiration: Methods and Application”**

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The amount of water used for agricultural purposes in the world is very high. For this reason, more efficient use of water in the agricultural land will be more important. It is also inevitable to reduce the amount of water used in agriculture in the future. The critical variable in determining the amount and timing of irrigation water in agriculture is the consumption of crop water (evapotranspiration).

As well known, evapotranspiration (ET) is a collective term for all processes through which water in liquid or solid form becomes atmospheric water vapor and it includes evaporation from bare soil, lakes and rivers and vegetative surfaces. It includes transpiration, which represents evaporation from within the leaves of plants through stomatal openings. The amount and/or distribution of evapotranspiration during the considered period is related to water usage of crops, photosynthesis, agricultural drought, planning of irrigation systems, management of water, yield etc. For this reason, accurate measurement and / or estimation of evapotranspiration is extremely important.

This course is about evapotranspiration and its components. In addition to this, methods and approaches used to measure and calculate evapotranspiration will be explained. Especially usage of micrometeorological approaches for determining of evapotranspiration will be emphasized. Energy balance components over crops; Bowen Ratio Energy Balance (BREB) and Eddy Covariance (EC) methods will be explained.

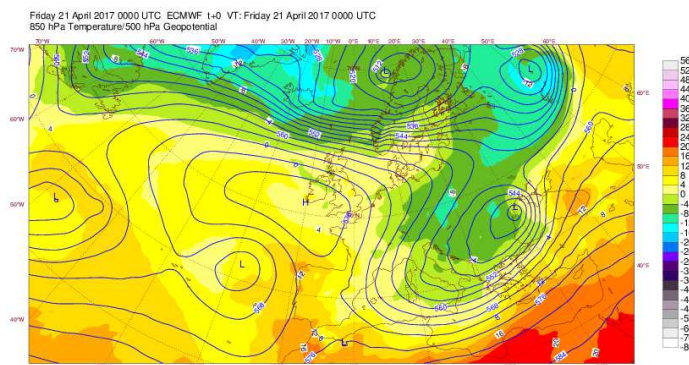
Especially BREB method will be described in detail and sensors necessary for measurement by this method and their properties will be presented. Advantages and disadvantages of micrometeorological approaches will be defined. In addition, an installed Bowen Ratio Energy Balance system and its components will be introduced practically to the participants. By the way, evaluation of data in order to calculate energy balance components and evapotranspiration will be presented.

## Cold Spell and Snowfall in Serbia – April 2017, case study

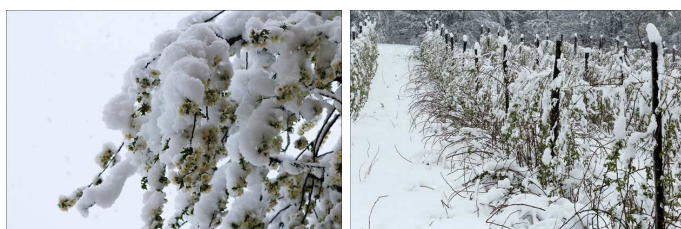
Ljiljana DEKIĆ, Ana MIHALOVIĆ

### Republic Hydrometeorological Service of Serbia

In the week 17 to 23 April unseasonal cold spell and snowfall hit the most of Europe. Deep trough was stretching from eastern Scandinavia to north-west of Russia into Central Europe with its base slowly amplifying and moving towards south-east Europe. This system brought very cold arctic airmass with the temperatures at 850 hPa between -5 and -12 deg C. In this cyclonic circulation extremely low temperature and widespread stratiform precipitation shield was observed.



Most of the different types of fruit, especially strawberries and raspberries, was in flowering in April and very sensitive to the spring frosts. Wet snow that fell can cause the breaking of a twig in raspberry also.

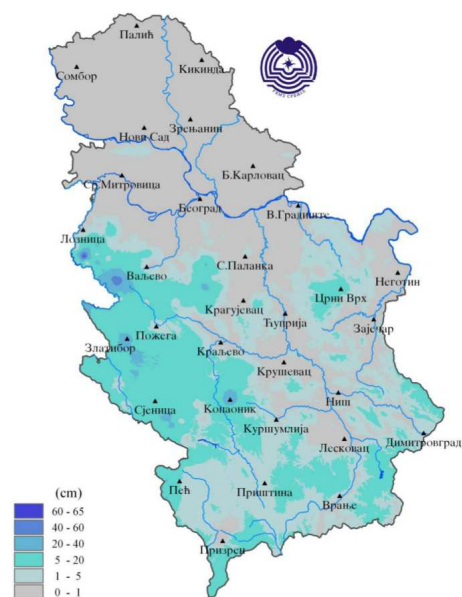


This case study will try to present what seasonal, extended range and medium range forecast is able to predict regarding extreme weather events and how far in advance. ECMWF global model, deterministic and ensemble products will be used for this study.

Seasonal forecast can't predict extreme events because we need statistics to handle lot of data and to consider anomalies (monthly or weekly) usually compared with model climate.

Extended range and medium range numerical weather prediction are very successful in predicting time of events and less successful in predicting exact values and amounts.

Better understanding of users needs and limitations in prediction atmospheric processes is crucial.



**Monthly and seasonal forecast application in  
agriculture: possibilities and limitations**

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Simplification, approximation and parameterization are inevitable elements of any modeling procedure but, at the same time, they define strong environmental boundaries of the system in subject, processes which will be taken into account and their mathematical representation. The simulation of the system behavior is good as much as initial conditions are known and mathematical equations are able to reproduce governing processes.

In attempts to simulate plant development modelers facing with two nonlinear dynamical systems: the atmosphere and plant. Non linearity implies that change in the system input is not proportional to change in its output. "Dynamical" is term in physics used to describe system which change of state is described by time-dependant function. So, in modeling plant-atmosphere interaction researcher should couple two systems changing and affecting each other over the time, and to take into account that knowledge about their behavior under certain initial conditions could not be simply extrapolated under new ones and that exact values of initial conditions are, actually, unknown. Quite a difficult task.

In case of atmosphere, one approach in dealing with this issue is based on shifting from deterministic to ensemble weather forecast. Deterministic forecast is based on assumption that initial atmospheric conditions are known and can be used to solve equations describing time evolution of variables of state, i.e. to run numerical weather prediction model (NWP). Ensemble weather forecast takes into account fact that atmospheric initial conditions are unknown and uses perturbations of observed initial conditions (as equally possible ones) to run NWP and to produce ensemble of weather forecasts.

In case of plant development modeling, shift from deterministic to ensemble forecasting implies to produce perturbed initial conditions related to weather, soil and plant. Since ensemble weather prediction is already available, as a first step, concept can be tested by applying this forecast as perturbed meteorological conditions to run crop model in order to obtain ensemble of estimates for yield and time of growing phase appearance. Effects of ensemble forecast application are assessed by comparing crop model outputs obtained using deterministic

[illegible]

## **The three rules of crop yield forecasting**

**Rene GOMMES**

**Senior agrometeorologist consultant**

The presentation states some views about the praxis of crop yield forecasting in the form of “rules”. The rules are empirical but derive from decade long practice of operational crop yield forecasting in an international context. Rule 1 “Crop yield forecasting is art as much as science” accounts for the fact that there are “good” and “bad” forecasters (both terms deserve defining!), that - with the same input data - issue different yield estimates because they know – or chose – different methods, because they have a more or less deep understanding of the system being modelled. The moral is that forecasters need a broad and solid technical background to allow them to chose methods purposely. The second rule states that “If statistics contradict agronomy, blame statistics; if common sense contradicts agronomy, blame yourself.” The rule insists that a crop forecast is not a data processing, statistical, remote sensing, crop modelling or a GIS problem. Nor is it a combination of those techniques, even if all now play a part. A crop forecast is an agronomic/agricultural problem! The third rule “All crop forecasting is statistical” is a reminder of the fact that crop forecasts must conform to the expectations of the customer, except, maybe, in a climate change impact context where relative values are usually sufficient. No forecasting method, especially the output of simulation models yields directly usable results, for a variety of reasons. The major one is that models cannot possibly take all factors into account, especially those associated with technology change (yield trends). All forecasts are produced for a real or virtual customer. The essence of the “rules” is that a “good” forecaster must eventually conform to the quality criteria of his customer.



## **Introduction to AQUACROP model**

**Anna DALLA MARTA**

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AquaCrop is a crop water productivity model developed by the Land and Water Division of FAO. It simulates **yield response to water** of herbaceous crops, and it particularly addresses conditions where water is a limiting factor in crop production. Nevertheless, as water availability is becoming a critical issue in many regions (included Europe) due to climate change and to natural resources overexploitation, AquaCrop is becoming a reference model used for guiding irrigation management in agriculture. One of the main strength of AquaCrop is the good balance between accuracy, simplicity, and robustness. It uses a small number of parameters and input variables that can be easily determined in the field or obtained from specific databases, nevertheless it is able to accurately simulate crop physiological processes and soil water budgeting processes. Moreover, it is freely available on web together with exhaustive documentation, training modules and tutorials. For all these reasons, it is particularly suited not only at research level but also for practical applications. Among them, AquaCrop can be used to predict crop production under different water-management conditions (including rain fed conditions, supplementary, deficit and full irrigation) or different climates; to optimize crop planning and management and developing irrigation strategies under water deficit conditions; to optimize crop water productivity; to compare different scenarios; to analyze yield gaps or impacts of climate change.

In general terms, a model is a simplified representation of a system, is a well-defined part of the reality. The system considered by AquaCrop is the crop-soil interaction system with its upper (atmosphere) and lower (depth and quality of water table) boundaries conditions able to affect such interactions. In fact, the core of AquaCrop, which is the water productivity equation, is inserted in a set of additional components: SOIL, with its water balance; CROP, with its processes, and ATMOSPHERE, with temperature, rainfall, evaporative demand and CO<sub>2</sub> concentration. Also, field management factors are considered (irrigation, surface management, soil fertility) as they can affect water balance, crop development and therefore, final yield.

The model output consists in biomass and crop yield for a given environmental condition. Additionally, the model gives a performance indicator which is ET water

productivity that is the amount of crop yield which can be obtained per unit of water lost by evapotranspiration.

The final crop yield is simulated in four steps: crop development, though the simulation of green canopy cover; crop transpiration, which is proportional to green canopy cover; biomass production, related to transpired water; and yield formation, calculated as a fraction of the total biomass through the use of the harvest index. Under non-limiting conditions, this calculation scheme simulates the potential yield obtainable for a given crop and environment. Nevertheless, real conditions often limit the full development and production of a crop. AquaCrop, by calculating the daily soil water balance and adjusting the water content in the soil profile, is able to detect stresses that might develop in the root zone. When a soil water stress is detected, leaf expansion, crop transpiration and biomass accumulation, and therefore the dry yield are then affected and the impact on the final production depends on the timing and the extent of the occurred stress.

The aim of this module is to make students familiar with AquaCrop, through a practical training on database management, input creation (meteo, soil, and crop files), model run, and output analysis.

More information on the AquaCrop, as well as full documentation, trainings and tutorials can be found at:

<http://www.fao.org/land-water/databases-and-software/aquacrop/en/>

Also notice that a new Open Source version of AquaCrop (AquaCrop – OS) was released and it is available for download. For more information, refer to:

*Foster et al. (2017). AquaCrop-OS: An open source version of FAO's crop water productivity model. Agricultural Water Management 181: 18–22.*

## **Adverse Weather Conditions and Crop Production Risks**

**Josef EITZINGER**

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Agricultural production is very sensitive not only to changes in mean climatic parameters but especially to a shift or changes in the occurrence and severity of weather extremes. Climate and climate variability however differ in their characterization by location significantly. In literature it was reported that climate change is leading to a shift in agroclimatic zones in Central Europe with significant consequences for crop production potential and risk due to increasing adverse weather conditions for crops. It should be noticed that while the changes in the climate conditions might improve conditions in the higher elevation, the soil and terrain conditions will remain unchanged.

Spatial and seasonal changes in climatic conditions include the frequency and intensity of extremes related to crop harmfulness and there are signs that these weather related phenomena (or adverse weather conditions) are changing the cropping risk pattern of specific agricultural crop production regions. For example, a several-fold increase in the frequency of some agrometeorological extremes are possible throughout Europe, especially regarding drought and heat. Even if weather extremes do not change in their absolute severity and frequency, seasonal shifts of their occurrence and its overlapping with critical crop phenological stages can change regional weather related crop production risks significantly.

There is already good knowledge on potential shifts of heat extremes and drought over Europe under climate change scenarios and their impacts on crop production. However, when it comes to regionalized weather related risk patterns with respect to extreme events, including also all potential weather related direct (abiotic) and indirect (biotic) risks and their combined impacts on specific crops and cropping systems, the knowledge and data base is still very poor. Available studies at the national scales with high spatial resolution frequently cover mean effects from climate change but rarely take changes in extreme events into account. In consequence, there is still a high uncertainty related to regionalized impacts on particular weather related risks for crops in climate impact studies and assessments for tailored adaptation options at the farm level. For developing tailored adaptation options to be accepted by farmers the socio-economic framework needs to be considered in the whole context as well.

Up to now the crop modeling community makes a big effort in the MACSUR and AgMIP projects ([www.macsur.eu](http://www.macsur.eu), [www.agmip.org](http://www.agmip.org)) to address combined drought and heat stress effects, which are considered as the main weather related crop production risks under climate change in Europe.

The weather related cropping risks can be quite different in their nature and seasonal frequency. During a crop growing season several weather related cropping risks can occur at different times, at the same time or can overlap. It can include all weather parameters and phenomena affecting directly and indirectly crop growing conditions as well as yield and damage potentials. Examples include: drought and heat directly limiting assimilation or yield forming processes; overwintering conditions of winter crops (especially strong temperature variations and snow cover conditions); frost risks at different phenological stages; weather risks for sowing and germination (erosion, soil hardening, inadequate soil temperatures); bad harvest conditions leading to yield loss; hail; wet periods and flooding; strong winds and thunderstorms (leading to lodging, N-leaching, erosion); high humidity and leaf wetness (forcing diseases); high temperatures (forcing pests) and many others. A crop's vulnerability to the severity and duration of these phenomena is different by species and variety, phenological status or occurrence of other crop stresses at the same time.



## **Basics of Agrometeorological Measurements**

**Josef EITZINGER, Erich MURSCH-RADLGRUBER**

**Institute of Meteorology, University of Natural  
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Crops and animals are directly or indirectly (e.g. through pests and diseases, soil conditions etc.) affected by weather and climatic conditions. The site-specific knowledge of weather and climatic parameters allows farmers to responding order to optimize crop growing conditions in short and long term scale. Examples are irrigation, pest and disease management and other risk protection measures. According to the specific application a different number and quality of respective parameters need to be known (and this is done by measurements) in order to implement measures in an effective way, such as planning the right irrigation timing and water application, or the timing of chemical applications in for crop protection.

For measuring environmental parameters in present are mostly electronic sensors used, measurements done by automated stations. Stations range from standard agrometeorological stations to specific small sensing units, depending on application. One of the challenges for agrometeorological purposes is that often the microclimatic conditions within the crop canopies are needed for detection certain developments, especially for pest and disease warning and forecast. For irrigation scheduling purposes, for another example, the soil water content need to be measured at the field of interest with its specific soil conditions. Considering the specific needs for agrometeorological applications (where measurements should represent accurately the specific microclimate) it is therefore often not suitable to use data from standardized weather stations (of national weather services, for example) which need to keep a specific setup of measurements and the measurement place worldwide (WMO standard).

The typical components of agrometeorological measurement stations (or systems) consist of a) sensors b) data collection and storing and c) data transfer and analysis incl. potential model applications. These components can be in various ways and by different methods combined. However, basic measurement techniques for sensing the parameters of interest are similar regardless of specific applications. Practically all weather parameters are of interest for manifold agrometeorological applications (air and soil temperatures, radiation, air humidity, soil wetness and soil water tension, wind, leaf wetness, precipitation etc.).

For the specific applications, minimum requirements of data generation need as well fulfilled. This includes not only technical parameters (such as accuracy, measurement ranges as well as robustness and lifetime of sensors) but also time and spatial resolution of needed data. These requirements strongly determine the costs for data generation (measurements) for specific applications and thus its cost return. By these reason there is always a need to optimize agrometeorological measurements (systems) in relation to its application.

On the open market we can find manifold options for sensors, measurement systems designed for various applications or users and in different quality. However, not only the technical aspects are important for a right and effective application, but especially the correct installation at the right place and time. This needs some basic understanding on environmental processes in order to avoid failures in specific applications. Finally, the maintenance of measurement stations / sensors and error checking of measured data need basic training and understanding of environmental phenomena, which will be addressed during the practical training course at the summer school.