CHAPTER I

REVIEW AND ASSESSMENT OF AGROCLIMATIC INDICES AND SIMULATION MODELS IN EUROPE

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Abstract. Many agrometeorological tools are available for agricultural research as well as for operational applications such as for stakeholder decision making. These tools range from simple indices or empirical models to complex, mechanistic models. Complex models can be used to simulate and analyse the manifold interactions in the soil-plant-atmosphere system, for example in the important field of climate change impacts on agricultural production. However, all kind of model results are related to different uncertainties and limitations, such as trends in technology and human activities, models representation of reality, lack of knowledge on system responses or lack of calibration data. This review provides, based on an European wide survey an overview of most widely used agrometeorological tools in Europe in research and operational use, related case study results, observed trends, problems in operational application and recommendations.

1. Introduction

A review and assessment of agroclimatic indices (including meteorological, climatological, and agrometeorological indices, currently used in agrometeorology) as well as crop simulation models relevant for various European agricultural activities was carried out in the frame of the COST734 action. The survey was based on questionnaires and a literature review. The detailed results are described in the COST734 report (Orlandini and Nejedlik, 2008) and two journal publications (Orlandini *et al*., 2008; Eitzinger *et al*., 2009).

During the past decades several software tools were developed for agricultural research and decision making purposes. For example, crop and whole farm system modeling, pest and disease warning models/algorithms, models for irrigation scheduling or agroclimatic indices can help farmers in decision making for crop management options and related farm technologies. For research purposes, models can also be used to simulate and analyze the complex interactions in the soil-plant-atmos-

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phere system. For example, they can be used to simulate climate change impacts on crop water balance and crop yields. Nevertheless, these modeled systems include many uncertainties and limitations resulting from unknown trends in future technology and human activities, a simplified representation of reality, lack of knowledge on system responses and lack of calibration data. Several research studies were conducted in Europe and worldwide in the field of model development, improvements, or comparisons of models. However, there are still many improvements necessary for model applications and related uncertainties, e.g. for climate change impact studies, as the presented COST734 studies reveal.

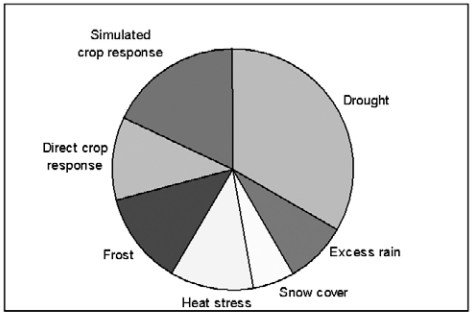
2. Agroclimatic Indices and Providers

Indices are explicitly defined by equations, whereas indicators reveal relationships used to quantify impacts. Both serve to simplify complex phenomena. Therefore, indicators can be converted into indices, once relationships are quantified and measurable. Indicators may also include output values from mechanistic models, which reflect simplified impact relationships.

Various indices are used in Europe for both operational and research applications. Indices are mostly used in agrometeorological monitoring and services operated by the national state bodies, such as in national meteorological and hydrometeorological institutes and their regional branches. Commercial agrometeorological services are scattered and usually focused on specific area such as extreme weather warning service or advisory services in case of plant protection against pests and diseases. In some cases, commercial companies selling products to farmers, such as weather stations, including also some technical support and agrometeorological services and/or forecasting models (mostly pest and disease warning and irrigation scheduling) as a service. Agrometeorological information is mostly produced by national bodies such as meteorological services, which run the meteorological networks, and so they are also the owners of the data. They usually cooperate with other national bodies or commercial companies such as agricultural extension services or insurance companies by providing them the data either free of charge or at low cost.

Research activities developing agrometeorological indices in Europe mainly focus on drought and crop responses such as phenology, and to a lesser extent, frost and heat stress (Fig. 1). The attention paid to research does not reflect the practical use of indices. For example, relatively little attention is paid to the operational monitoring of drought and heat stress, while the majority of countries report the research activities in this field.

Fig. 1. Frequency of reported application of agrometeorological indices in research related to their purpose, according to the COST734 survey (Eitzinger et al., 2009).



A large number of various indices including literature is reported in Orlandini et al. (2008).

Drought indices quantify the lack of water for specific periods of time, such as the negative deviation of precipitation from the normal in the case of meteorological drought indices. Meteorological drought indices, however, do not always reflect well the level of crop water shortage. Therefore, agrometeorological drought indices, focus on crop water balance of crop stands during the plant growth and development cycle. The general problem of these indices is to include both physical and biological properties of crops to reflect their sensitivity and limitations towards the lack of water supply during the vegetation period. A related problem is the definition of the time step used to calculate the particular indices. Therefore, each drought index performance is related not only to a specific application (e.g. for crop water stress detection, climatic water deficit, etc.) but also to the environmental conditions (e.g. different indices show different sensitivity under changing climatic conditions). Therefore, new studies also recommend a combined application of drought indices, optimized for the relevant environmental conditions, to improve the monitoring performance for various applications. An example is a combination of remote sensing based indices (e.g. perpendicular drought indices) with meteorological or agrometeorological drought indices. In Greece, for example, the two remote sensing based drought indices Reconnaissance Drought Index (RDI) for hydrometeorological drought and Vegetation Health Index (VHI) for agricultural drought (Kanellou *et al.*, 2009a) are preferred beside the existence of conventional drought indices such as Deciles of precipitation, RDI using precipitation and potential evapotranspiration, Palmer Drought Severity Index (PDSI) using precipitation, potential evapotranspiration and the available water capacity (Kanellou *et al.*, 2009b), the Standardized Precipitation Index (SPI) and the Rainfall Anomaly Index (RAI).

Most of drought indices focus on pastcasting, while few of them on nowcasting, as reported in the COST survey. These indices are often applied locally or regionally as they have to use multiyear measured values of the particular parameters recorded or calculated for a certain locality. Many of the indices in use are rather complex and deal with water balance components and precipitation measures. Indices including the calculation of water balance components are used with various modifications in almost all countries from national to farm level extent. Both indices, based on water balance components and on precipitation for a given period, are mainly produced by national weather services, as they run the meteorological networks at regional and national levels. Some institutes additionally use water balance outputs of crop models like WOFOST to define the days with the lack of water for specific crops.

Among the standard indices, the standardized precipitation index (SPI), Palmer drought severity index (PDSI), percent of normal precipitation and rainfall percentiles are in operational use among national services in Europe and at the Drought Management Center for South eastern Europe (DMCSEE). Relevant maps are published on the web page <http://www.dmcsee.org/>, and they are updated once per month.

Excess rain is mostly estimated from daily cumulated precipitation measurements. Further to this parameter, the rainfall intensity is measured either by pluviographs or by weight rain gauges providing online signal. The majority of rainfall parameters are issued by the standard forecast of each meteorological service, mainly at the regional scale. Many of the services also provide special rainfall maps in their pastcasting, forecasting and now casting, identifying the areas with high precipitation and/or anomalies. For instance, the INCA system has been applied in Austria since 2003 to spatial past-, now- and forecasting of various weather parameters and uses radar and station data to produce precipitation maps (http://www.zamg.ac.at/incaanalyse/). In Greece, for example, apart from high precipitation pastcasting maps, an operational-research application of the non-hydrostatic model LM-COSMO of HNMS (Hellenic National Meteorological Service) has been used for forecasting excess rain events and the simulation of severe thunderstorms (Avgoustoglou, 2002).

Heat stress is an important but complex phenomenon, depending on the definition and the sensitivity of the parameter. Factors such the height of temperature, duration, and rate of increase of the temperature as well as air humidity, radiation, and wind can modify the heat stress level of living organisms. The critical thresholds of temperatures for crops differ much and they vary also according to the plant development stage. A threshold of heat stress usually refers to the daily mean temperature, over which a detectable reduction of growth or damages on plant begins. In