STSM SCIENTIFIC REPORT
"Regional Assessment of Drought Risk in Slovenia and Switzerland under Current and Future Climatic Conditions"
COST Action: 734

STSM Applicant: Andreja Sušnik, Department of Agrometeorology,
Meteorological Office, Environmental Agency of the Republic of Slovenia
(Slovenia)

Host: **dr. Pierluigi Calanca**, Agroscope Reckenholz-Tänikon (Switzerland)

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- ## Purpose of the visit

Drought characteristation is referred to as the most complex and diverse task in agrometeorology. The drought episodes that took place from 1998 to 2007 brought considerable attention to the topic. Recent efforts to improve drought monitoring in many countries have provided new decision-support tools and methodologies in support of drought prepardness planning. The most common approach are drought indices, which enable to identify onset and development of drought, its severity and spatial extent. Drought indices are dimensionless measures of anomalies in the water availability. They are evaluated using meteorological data a additional information that strongly depend on the user requirements.

The main motivation of STSM was to promote drought risk research in Slovenia and Switzerland with a focus on the detection of agricultural drought. The possibility to use IRRFIB to evaluate crop water availability was tested. IRRFIB is a simple model that nevertheless integrates information concerning multiple parameters (soil moisture, actual evapotranspiration, crop water balance), that are important for the assessment of crop water availability.

Equally important was the second part of work, the training of participant on how to develop site-specific climate change scenarios using a stochastic weather generator. This is an important step for the assessment of the vulnerability of agricultural crops to future episodes of droughts. The use of a common methodology opens the possibility for targeted climate change impact studies in both countries.

The outcome of this STSM will be a contribution to COST action 734 and more generally to the drought modelling community and some results could be used also in the frame of Drought management center for south eastern Europe-DMCSEE.

- ## Description of the work carried out during the visit

The work was performed as follows:

  - Comparison of measured and simulated crop water deficits. Simulated grass water deficit by the crop water balance model IRRFIB were compared with some measured data (TDR soil moisture content) obtained for specific sites in Slovenia and

Switzerland on daily scale. With Penman-Monteith method crop evapotranspiration was estimated. Representative soil and crop characteristics were used in the study.

- Evaluation of methods for estimating reference evapotranspiration. For future applications of IRRFIB in combination with climate change scenarios, a comparison of Penman-Monteith with Priestley-Taylor method for estimating reference ET was performed (Fig 1).

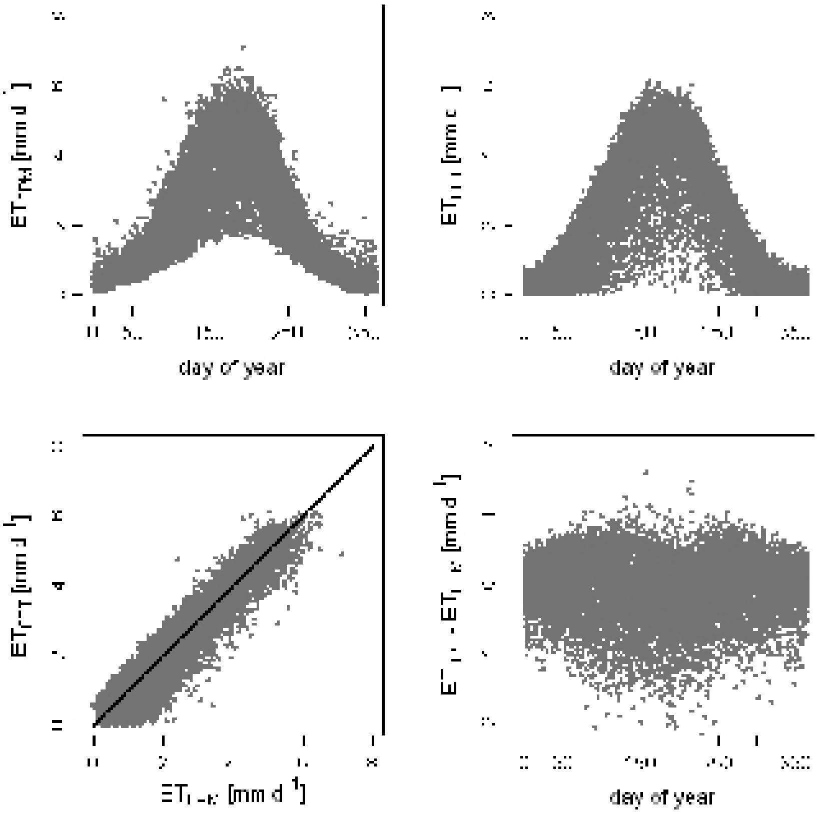


Fig. 1: Daily estimates of the reference evapotranspiration, ET_0, by the Penman-Monteith (PM, top left) and Preistley-Taylor equation (PT, top right) at Ljubljana over a period of 40 years. The bottom panels show their relation (left, with 1:1 line added for reference) and the seasonal course of their difference (right).

- Preparation of climate change scenarios sets for specific sites in Slovenia and Switzerland with LARS-WG stochastic weather generator (Semenov and Barrow, 1997, Semenov et al., 1998; Semenov, 2007). Data for the period 1961-2008 were used for calibration of thek weather generator. Daily weather data were generated for a choice of 4 GCMs, 3 emission scenarios and 2 time frame windows.
- Quantify uncertainty and reliability of climate scenarios. To assess their reliability, the scenarios were compared with those prepared using the M&Rfi weather generator (Dubrovsky, 1996) in the framework of the COST 734 project AgriClim. Results of the comparison are shown in fig. 2

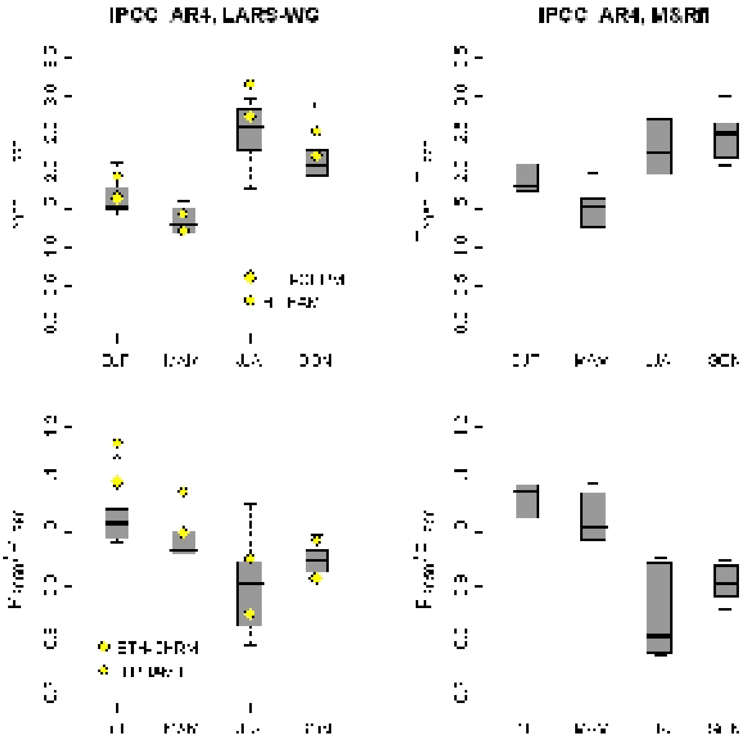


Fig. 2: Changes in seasonal mean temperature (top) and rainfall (bottom) as simulated by LARS-WG (left) and M&Rfi (right) for Oensingen. The box-plots show the uncertainty range reflecting the global boundary conditions given by 3 global climate models and 2 emission scenarios. For comparison, the climate change signal from 2 PRUDENCE scenarios is also displayed in the panels on the left-hand side.

- Assessment of the risk of drought in Slovenia and Switzerland under future climatic conditions. The climate scenarios were used to drive IRRFIB and the output was analysed with respect of the drought index developed by Sušnik (2006). A statistical analysis was performed on the latter to estimate the probability of drought events under future climatic conditions (Fig. 3).

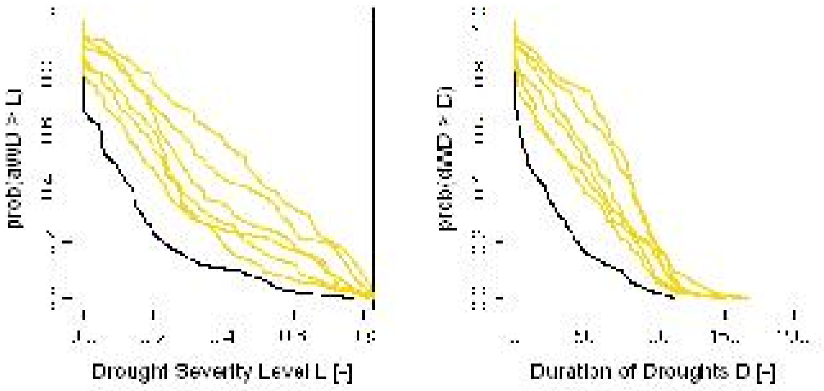


Fig. 3: Probability of exceeding increasing level of drought severity (left) and duration of critical conditions (right) for the baseline (black line) and 6 selected climate scenarios (yellow lines) in Switzerland. The baseline refer to 100 years of synthetic daily data generated by LARSWG assuming current climate conditions. The scenarios were obtained for the nominal time window 2040-2060.

- Preparing a draft for a paper on the outcome of the STSM, to be submitted to an international journal.

Model IRRFIB aims and utility

Basic for model calculations are physical connections among soil, crop and weather. The IRRFIB model calculates reference daily water balance for different regions and represents agricultural decision support tool in the frame of agrometeorological information system. Its recent development enabled quick and accurate transfer of information to end users. An open code solution developed in Linux platform is based on the PostgreSQL database. In the IRRFIB model meteorological data, soil data, crop data and agrotechnical data are integrated. Reference evapotranspiration (ETo) is calculated by Penman-Monteith equation using air temperature, wind speed, air humidity and net radiation. Penman-Monteith's was the most suitable method for evapotranspiration calculation in Slovenia. Users can choose among different crops or crop varieties and soil types. Detailed description of the modeli is available in Sušnik (2006).

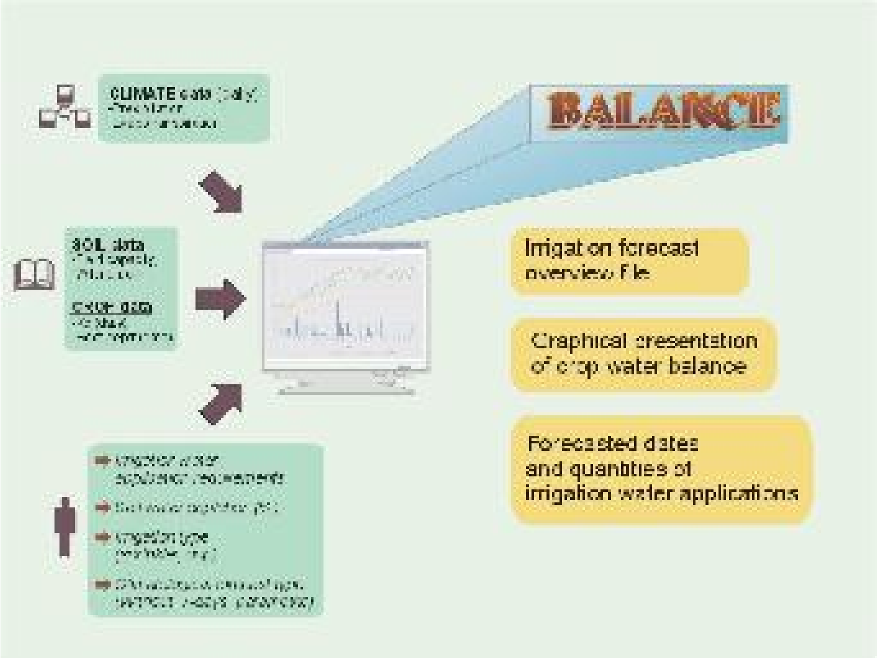


Fig. 4: Flow chart of "exe" version of IRRFIB.

Methodologies (crop water balance, agricultural drought index)

At this moment there are two versions of IRRFIB model. So called "exe" version is available and can be download and install to the registered user computer (Figure 4). The second internet version of the model is running online. The user can choose different crops, soil types and data from different weather stations (Figure 5). Water balance status represents cumulative difference between precipitation and reference evapotranspiration. Daily water deficit calculations are made for the vegetation period from April to October.

The patterns of crop water deficits and droughts appearance and their duration are changing (Sušnik, 2006, Bergant et al, 2007). For the estimation of daily, weekly and seasonal intensity and duration of water deficit in the vegetation period the model IRRFIB was used. The merging information about duration and intensity of water deficit in the vegetation period as agicultural drought index

(ISv) was calculated according to the IRRFIB methodology described by Sušnik (2006).

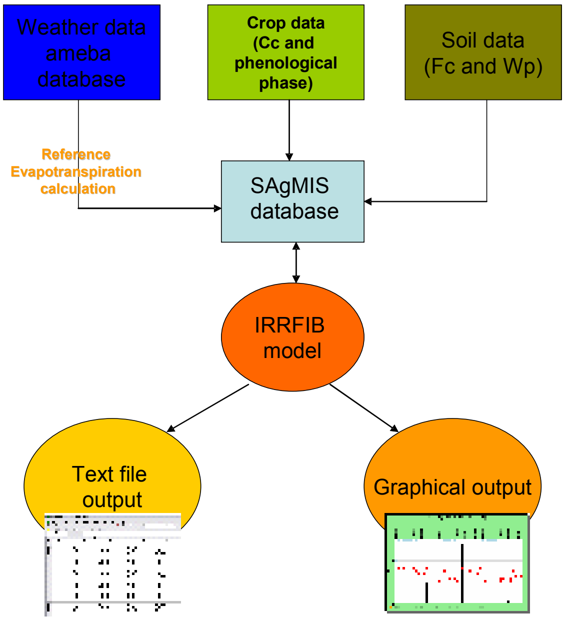


Fig. 5: Flow chart of internet version of IRRFIB.

Implementation (NWP & weather generator LARS-WG)

Recently progress is focused on IRRFIB model forecast implementation by using numerical weather products and weather generators datasets.

The weather forecast in Slovenia issued for the purpose of mending local weather information is among others based also on weather information derived by limited area numerical weather prediction model ALADIN/SI. ALADIN model forecast has evolved throughout the past ten years and today customer can acquire progressively better and useful information. The composition of interpretative weather elements forecasts from model output variables is becoming integral component of weather service in Slovenia. Since numerical weather prediction models became operational and the quality of the forecasts is increasing gradually, the tailored products can be transmitted directly to the customers. Daily water balance forecast for agricultural purposes is based on existing infrastructure. Forecast of the water budget components of chosen area was obtained by combining information about soil properties and crop characteristics. Based on numerical weather model ALADIN/SI 24 and 48 hours forecasts of water balance are calculated. For weekly forecast ECMWF 7 days forecast is used. Middle range weather forecast derived from ECMWF numerical model is currently in the testing phase and it is not reachable by end users up to now. Recently progress of radar precipitation data inclusion has started .Irrigation model scheduling represents daily actual water consumption for selected crop and soil and it is selected by the user.

Water balance forecast analysis example in 2003

The forecasts of 24 and 48 hours water balance were calculated and added to corresponding observations in order to get dynamics of water balance for the vegetation period from April till September 2003. The results were obtained for five meteorological stations sited in the major agricultural regions in Slovenia.

Generally, the forecasts are of good quality. There are repeated cases of failures in forecasts of precipitation which are recorded after a prolonged period of stable weather. The overestimation of forecasts is recorded for central Slovenia, on the contrary forecasts for NE and SW parts are underestimated. The study of RMSE between observations and 24 or 48 hours forecasts of water balance are lowest in NE part of Slovenia, RMSE is 0.18–0.25 mm for daily forecast and 0.42–0.46 mm for two days forecast. In other areas the situation is a bit different mainly due to the greater amount of precipitation. In this case, the RMSE for 24 hours forecast is 0.27 mm and 0.51 mm for 48 hours forecast. Generally, forecasts give better score in the areas with lower seasonal precipitation (Figure 6). Due to the fact that 2003 was extremely dry and hot year absolute precipitation errors were lower. Higher accuracy of water balance forecast during dry years is evident. In this case RMSE were much lower than in other more humid vegetation seasons (Table 1).

Tab. 1: Comparison of observed and forecasted water balance by RMSE (in mm/day)

Stations/RMSE	24 hours	48 hours
Bilje pri Novi Gorici (SW)	0.27	0.44
Ljubljana (central)	0.29	0.55
Maribor (NE)	0.18	0.42
Murska Sobota (E)	0.25	0.46

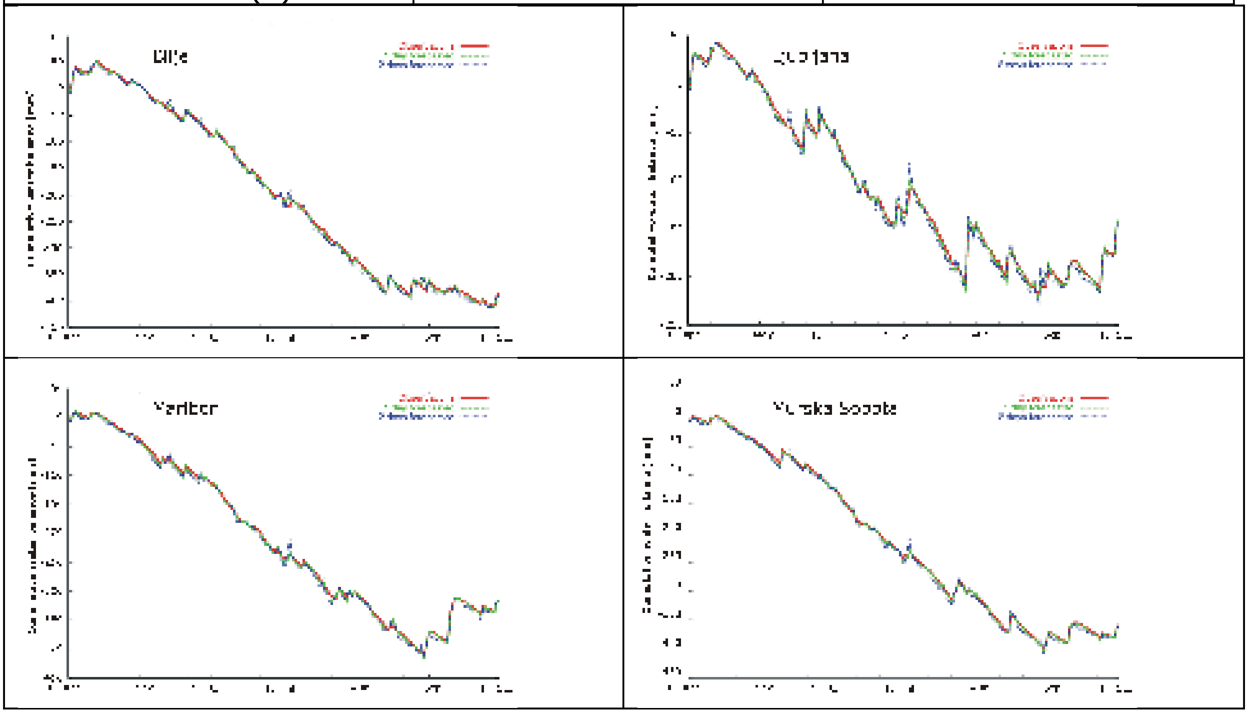


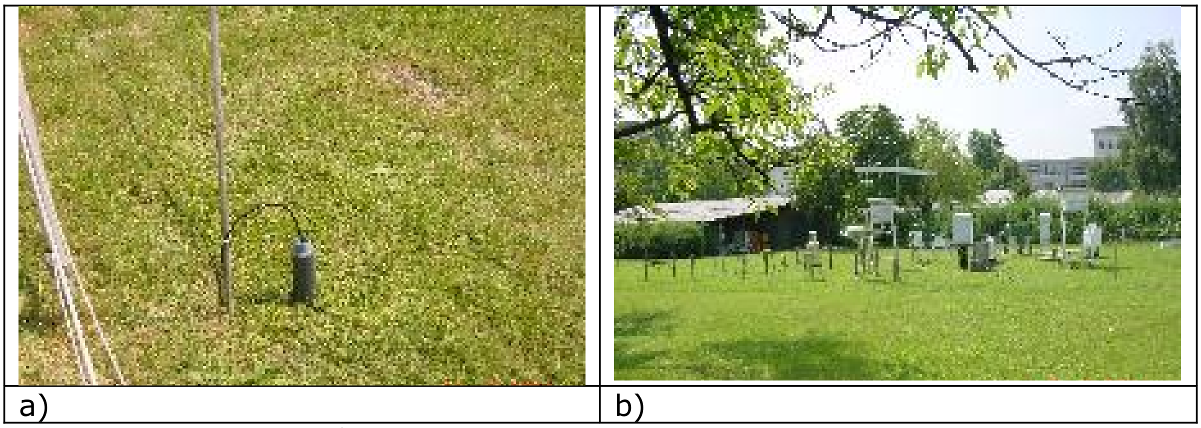
Fig. 6: Vegetation seasonal plots of observed and forecasted (24 and 48 hours ahead) cumulative water balance for tested areas

Validation and constraints

Water content measurement with TRIME® -EZ sensor

The TRIME® -EZ (Time domain Reflectometry) sensor for continuous and non-destructive determination of volumetric soil moisture was used for IRRFIB model validation. The measurement device consists of electronic sensor with integrated TDR. The operating principle is based on measurements of dielectric constant of a material. The moisture content is calculated inside device.

Measurements took place daily from July 23 up to September 6, 2004 at the measurement site of meteorological station in Ljubljana. The comparison of soil water content estimated by model with measurements showed strong correlations during the tested period ($r^2 = 0.94$).



a)

b)

Fig. 7: Sensor TRIME® -EZ (a) and observation site of meteorological station Ljubljana(b).

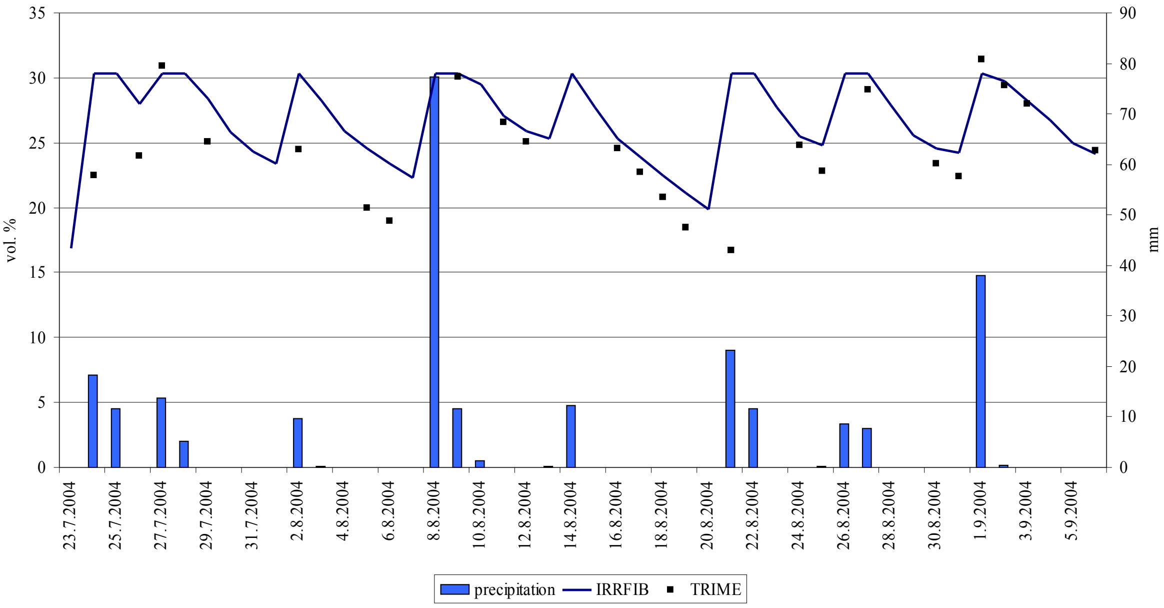


Fig. 8: Comparison of soil water content measured TRIME® -EZ sonde and estimated by IRRFIB model for Ljubljana in the period from 23.7.2004 – 6.9.2004.

Original IRRFIB model was developed exclusively for water irrigation forecasting on daily basis. For several cases limited number of input data (meteorological data, phenological stages, soil data) are available and therefore the calculations by IRRFIB represent rough approximations. Very important issues is interpolation of missing data. Other constrains of the model are:

- estimation is based only on one soil layer,
- not included complete water repartition in the soil-vertical and lateral flow,
- simplification of soil-water-plant-atmosphere balance process.

Uncertainty

The biggest uncertainty of the model is availability of input data. Meteorological data are measured on climatological or automatic weather stations. Frequently data time series have gaps or are not available for the site. Precipitation is one of the weakest components of water balance scheduling. Therefore missing values have to be filled using interpolation techniques with data from neighbouring stations. Also in situ soil and crop data should be imported into the IRRFIB model files but they are often not available. Only for few plants crops coefficients, root depths and model parameters are measured for the Slovenian region and therefore a lot of data from literature are used.

End user benefits

Estimation of crop water use from meteorological data is essential to achieve better water use efficiency and detect water stress and drought development. The compilation and processing of agrometeorological information is important although dissemination of data is key element in this field.

Perspective

Growing concerns regarding the increase of water shortage call for greater efforts to establish future strategies of management with natural resources and their connection to climate and its variability. Under climate conditions, it is expected that irrigation water demand will further increase, aggravating the competition with other sectors whose demand is also projected to increase (Kajfež-Bogataj, Sušnik, 2007). Inappropriate management of land use with severe climate events can result in increased probability of nutrient loss due to leaching and land degaradation. The potential exists in improvement of drought management and therefore reducing risks also taking into account agroecological zones. Drought monitoring represents a useful tool for assessment analysis like zoning due to drought vulnerability. The progress on more detailed input layers should be performed. Therefore more collaborative activity of agricultural institutions with other competent institutions should be established and international cooperation is neeed.

The application of weather and climate forecast information to improve the response activities is essential. While weather forecast of course remains the core application, use is being made of running real time operational models for water balance scheduling in agricultural practice. Decreasing of forecast error by ALADIN can enable more accurate prediction of water consumption and other related activities in short-term decisions in agriculture practice like irrigation.

Simulations of water deficit behaviour in the future will be crucial for future adaptation of agriculture to climate variability and change The methodological recommendation of agricultural practice should taking into account also hints from future climate scenarios data (climate zoning, drought vulnerability). The role of drougt monitoring and more accurate identification of agricultural drought will be an important segment in future agricultural adaptation process .

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- **Description of the main results obtained**
  - Priestley Taylor equation adjustments were peformed and tested against Penman-Monteith (systematic differences are still present and should be further investigated);
  - Adjusted version of IRRFIB can be used to quantify water deficit of grassland in different climates;
  - Performance of LARS-WG was tested;
  - A set of climate scenarios for tested locations were prepared ;
  - Water deficit and drought risk was evaluated for chosen scenarios.

- **Future collaboration with host institutions (if applicable)**
  - Extension of drought research in both countries (in Slovenia also in collaboration with DMCSEE);
  - Extension of agricultural drought analysis to other crops;
  - Development of climate scenarios for other sites in Slovenia and Switzerland.

Depending on the financial possibilities of COST and progress of the COST 734 activities, a second STSM (from Switzerland to Slovenia) is envisaged by the applicant and host.

- **Projected publications /articles resulting or to result from the STSM (if applicable)**

The applicant and host of the STSM are preparing a manuscript entitled »Likelihood of a 2003 drought under future climatic conditions« for submission later this year to an international journal.

- **Confirmation by the host institute of the successful execution of the mission**

The host of the STSM (Dr. Pierluigi Calanca, Agroscope Reckenholz-Tänikon, Zurich, Switzerland) confirms that the STSM was succesfully executed according to the working plan submitted on May 12, 2009, to the COST office.

Pierluigi Calanca, 23.06.2009

- **Other comments (if any)**