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DROUGHT PREPAREDNESS, MITIGATION AND MANAGEMENT

– Innovative approaches for the agricultural sector

- *New hydro-meteorological forecast products by IMPREX allow for more proactive drought management in the European agricultural sector*
- *New drought risk management tools help mitigate the agricultural sector's vulnerability to prolonged droughts*
- *Innovative products contribute to stable economic development and increased European food security*

The likely increase of droughts, affecting local and regional economies, poses a major threat to the agricultural sector in Europe and would lead to substantial economic losses. The unusually hot and dry European summer of 2018 resulted in severe water scarcity. Food producers suffered, not only in southern Europe but also in northern parts of the continent where agricultural systems are not well adapted. In the future, water will become even scarcer in many regions due to climate change impacts.

Drought risk can be defined as the interaction between natural drought hazards and their impacts on society and the environment. IMPREX developed approaches to assess drought risks that consider both the probability of drought-related hazard events and their possible socioeconomic and environmental consequences. This factsheet will outline key IMPREX contributions.

Proactive drought risk management for drought-induced disasters

To improve proactive drought risk management within the agricultural sector, an objective knowledge base and adequate tools and methodologies are needed. Calling for a more sustainable solution, UNISDR (2009) suggests a systematic process to prevent, mitigate and prepare for drought-induced disasters. This includes climate change analysis, prediction of drought damage under certain conditions and assessments of the effectiveness of management options and interventions. This is offered within IMPREX.

Economic benefits from rational decision-making facilitated by probabilistic forecasts

Improved weather and climate services, such as improved temperature and rainfall forecasts, are indispensable for

efficient decision-making and drought management within the agricultural sector. The IMPREX research project has contributed substantially to improved hydrological and meteorological forecasts and their uptake. Together with end-users, IMPREX developed probabilistic approaches that quantify and visualize uncertainties, improving the basis for efficient and risk-based decision-making.

Forecasts with longer lead times enhance decision-making processes

IMPREX identified considerable interest in predictions with an extended lead time, especially seasonal predictions. Forecasts with an extended lead time enable the agricultural sector to adopt better logistical planning of resources and operations, and decision-makers to take preventive actions to reduce the impacts of droughts.

IMPREX incorporated seasonal forecasts of precipitation into the AQUATOOL decision support system for water resources management and risk-based water allocation. Risk mapping is facilitated through the FRIDA framework for index-based drought analysis, which quantifies impact-based indices for efficient drought management and through a methodology for efficient water accounting that synthesizes climate change impacts on agricultural water use. To improve the approach to complex interactions, IMPREX offers tools for quantify drought impacts and a framework to assess the cost-efficiency of adaptation measures to better cope with water scarcity. IMPREX also developed the drought risk assessment and management tool as well as a methodology for risk-based allocation and a system dynamics model.

IMPREX TOOLS:

- Improved AQUATOOL modules
- Framework for Index-based Drought Analysis (FRIDA)
- Water accounting methodology to synthesize climate change impacts on agricultural water use
- Drought risk assessment and management tool
- Methodology for optimization of water allocation
- The system dynamics hydro-economic model of adaptation to droughts

AQUATOOL – A Decision Support System (DSS) for water resources management and risk-based water allocation

The AQUATOOL decision support system maps the essential hydrology of a basin and its demands to then track the consequences of specific hydrometeorological scenarios on this system. By explicitly representing water supply risks, an optimization of the basin system can be generated. The tool is used by a wide range of water resources managers in Spain and other places.

The IMPREX project upgraded AQUATOOL with an improved risk-based approach. This enables more realistic, probabilistic risk assessments and scenario generation through the incorporation of tuned meteorological forecasts. IMPREX also provided an incremental improvement by addressing multi-sectoral water demands in the risk profile.

AQUATOOL facilitates the generation of data needed for river basin and drought management plans

The tool has the potential to establish the basis for European river basin and drought management plans, as demonstrated by its current use in most Spanish river basins.

AQUATOOL consists of several modules that can be combined in various ways to adapt to specific user needs. Three important AQUATOOL modules have been used and further refined within IMPREX:

- **SIMGES** – a general water management and allocation module for river basins
- **SIMRISK** – a risk assessment module designed for river basin management
- **EVALHID** – a hydrological module focussing on water availability within a river basin

AQUATOOL supports efficient and effective river basin management by enabling high-quality drought risk analyses and measuring efficiency as well as long-term planning within a river basin e.g. water management and allocation simulations and probabilistic assessment of water shortage and vulnerability.

FRAMEWORK FOR INDEX-BASED DROUGHT ANALYSIS (FRIDA)

– A machine learning-based tool to define impact-based indices for drought monitoring and management

Drought sensitivity to hydro-meteorological variables is different for each river basin as it depends on factors such as topography and land use. This sensitivity can be captured in one or several drought monitoring indices that can contribute to the development of the drought management plans as put forward by the EU Water Framework Directive. To support the definition of drought indices, IMPREX developed a Framework for Index-based Drought Analysis (FRIDA), which generalizes and automatizes the selection process of the variables used in the index formulation and facilitates the stakeholder participation process.

FRIDA can be used to define basin-customized drought indices in any European drought-prone river basin.

FRIDA relies on state-of-the-art feature extraction, machine learning, data fusion and artificial intelligence techniques for the synthesis of a heterogeneous and multi-source dataset (e.g. water stored in reservoirs, river flow and precipitation) into a compact basin-specific drought index. This index can be used by river basin managers, at the local, regional and national scales to monitor the onset and evolution of drought events and to support operational drought management.

WATER ACCOUNTING METHODOLOGY TO ASSESS CLIMATE CHANGE IMPACTS ON AGRICULTURAL WATER USE

– A single framework to extract information from multiple river basin-level studies

Water accounting is the process of communicating information related to water resources and the services generated from consumption use in a geographical domain (such as a river basin, a country or a land use class) to users such as policymakers, water authorities, managers, etc. Water accounting can be useful to standardize information from a wide range of sources and can extract policy-relevant indicators.

Pan-European information on climate change impacts on water resources for agriculture is scattered: while there are many river-basin level studies, they currently do not reach the European decision-making-level. IMPREX developed a water accounting framework which allows a standardized examination of climate impacts on water resources availability and use for agriculture across multiple studies and river basins. Typically, water accounting is used to report on past water resources, but here it has been used to map future climate change impacts.

- **Use of a single framework to synthesize river basin-level climate impact studies**
- **Methodology assures that local system knowledge (infrastructure, socio-economic, legislative, etc.) is not neglected in assessments at the pan-European level**

The IMPREX methodology for water accounting is especially useful for channelling and presenting different climate impact case studies (and data) in one single framework, enabling a direct comparison of different European river basins. The approach has been tested and validated based on five European river basins and has the potential to integrate and synthesize a much higher number of studies across Europe, thus generating information for policies on water and agriculture at the European level. Information on climate impacts and the potential for adaptation measures can be assessed, with the principal advantage that the underlying data sources are backed up by local experts at the river basin-level.

DROUGHT RISK ASSESSMENT AND MANAGEMENT TOOL

– Quantitative risk-based decision-making for fresh water management

IMPREX developed the drought risk assessment and management method and tool, including a cost-benefit analysis of current water resources management practices as well as a quantification of cost-efficiency of alternative drought risk reduction strategies.

A comprehensive risk profile as a reliable basis for decision-making

The IMPREX drought risk assessment and management tool enables an integrated risk assessment for present and future situations, including an analysis of the effects of climate change and the effectiveness and benefits of adaptation measures. The cost-benefit module also allows for an innovative approach to water allocation. The tool and underlying method provide proactive drought risk management within the agricultural sector and between different sectors that rely on water, such as waterway transport. The method delivers a systematic process to mitigate and prepare for drought damage.

The result of the tool is a comprehensive, objective risk profile that offers a good basis for decision-making. The profile is the outcome of a stakeholder process substantiated with data and model results. The risk profile identifies opportunities and measures and quantifies their subsequent consequences as a yearly expected damage value. By combining drought damage with the probability of drought occurrence, it is possible to quantify drought-related risks in present and future situations while taking into account the influence of climate change associated with various adaptation measures. Examples are controlling water flows in major waterways, local infrastructural solutions to supplement water and local adaptations by the end-users.

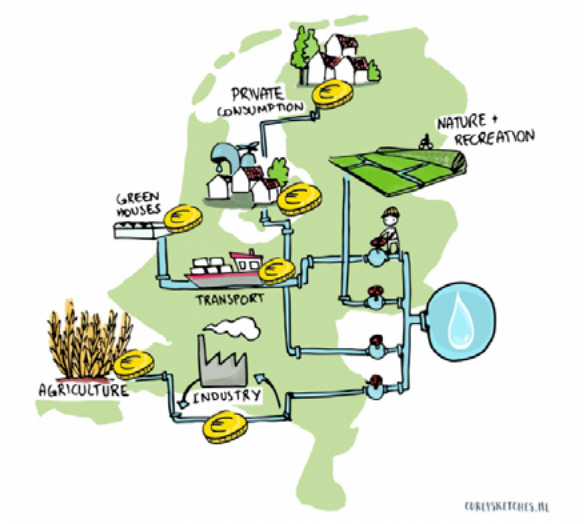

Figure 2: A schematic overview of a drought risk assessment framework

FORECAST-INFORMED WATER MANAGEMENT

– An approach to reduce multi-sectoral conflicts

IMPREX adopted a cross-sectoral approach to analyse river basin management strategies and investigate the value of IMPREX forecasts for different end-users. The approach has been demonstrated in the Lake Como basin, which is characterized by the presence of competing multi-sector interests (e.g. flood control, irrigation supply, hydropower generation, environmental protection).

IMPREX established a participative co-design approach with local stakeholders to develop a set of evaluation indicators that take into account differing interests. The IMPREX forecasts value was quantified in terms of end-user economic benefits from using forecast information to prompt anticipatory operations and manage extreme events. Moreover, IMPREX forecasts allow the reduction of existing conflicts across sectors by supporting the identification of compromise management solutions that better balance the competing demands.

Optimal water allocation between sectors based on IMPREX' forecast accounts for:

- **Economic gains with an average of 1.2% of farmers' annual profit, which raises up to 1,6% during extreme droughts for irrigated agriculture**
- **Economic gains with an average of 1,6% of the annual revenue for a company in the hydropower sector**

These cost savings are projected to increase under climate change conditions.

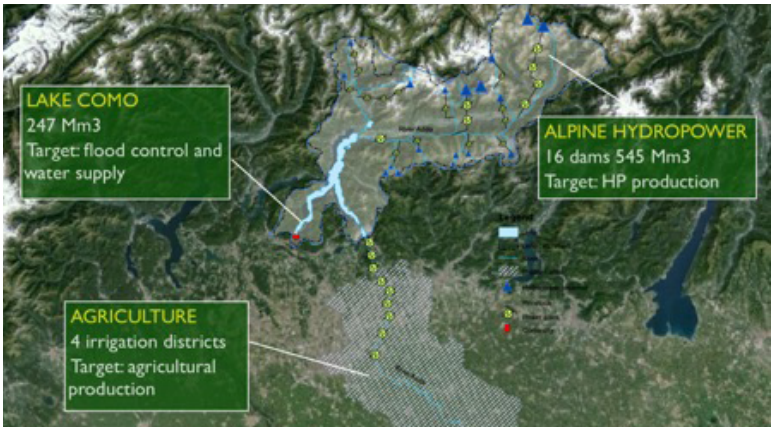

Figure 3: Lake Como basin and its multi-sectoral stakeholders

THE SYSTEM DYNAMICS HYDRO-ECONOMIC MODEL OF ADAPTATION TO DROUGHTS

Within IMPREX, cross-disciplinary knowledge has been integrated into the development of a new system dynamics modelling tool for the assessment of adaptation investment scenarios. Based on a stakeholder consultation process, the model delivers a qualitative and quantitative representation of the network of dependencies that affect water supply, demand and value.

Integrating scientific and end-user knowledge as part of a participatory approach enhances operating efficiency

The system dynamics model provides advice on optimal investment scenarios in adaptation measures. Consulted stakeholders include regional, local and river basin authorities as well as researchers from relevant fields, including experts in water resource management and economists.

The model consists of two modules: a regional system dynamics economic module linked to a hydrological module. Projections from regional climate models serve as input for the hydrological module to explore the impact of different climate scenarios. In addition, different socio-economic scenarios and adaptation strategies have been explored. In particular, regional investment flow scenarios have been simulated, which will help improving water use efficiency in the face of upcoming droughts.

CASE STUDY – Drought Management within the Júcar River Basin in Spain

The Júcar river basin, a typical Mediterranean basin, suffers from recurrent multi-annual droughts. Adequate adaptation management strategies to increase resilience to both excess and lack of water are essential to buffer economic risks.

Long-lasting and extensive droughts make the allocation of water resources among competing sectors especially important. Within the Júcar river basin, agriculture accounts for about 80% of the total water demand. With its heavy dependence on sufficient water resources, the sector is vulnerable to restrictions in the water supply, which lead to reduced yields, loss of annual crops, and persistent damage to permanent crops. These experiences highlight the importance of implementing a proactive drought planning and management approach in order to cope with extensive droughts.

> *AQUATOOL improves drought risk management by delivering information on efficiency of concrete drought risk adaptation measures, thus avoiding temporal and permanent loss of crops due to water deficit*
> *- Teodoro Estrela, CHJ*

AQUATOOL has been tested and implemented within the Jucar river basin and many other Spanish river basins. The tool provides the basis for efficient operational management. The Júcar river basin Partnership (CHJ in Spanish), a public-private participatory institution that unites all relevant stakeholders of water resources management within the basin, manages and allocates water among urban, agricultural, hydropower and industrial users within the Júcar river basin. Within the framework of IMPREX, CHJ together with the Technical University of Valencia (UPV) applied the AQUATOOL decision support system, especially the modules EVALHID, SIMGES and SIMRISK, for hydrological modelling improved by the incorporation of seasonal forecasts, to simulate the performance of the water resources system in general and to conduct a risk assessment for selected adaptation measures specifically.

> *The use of this combination of modules will help to improve early warning systems and strategic decision making during droughts to ensure urban water supply and prevent water quality problems - Javier Macian, Aguas de Valencia*

The AQUATOOL modules provided a clear added value for CHJ by showing the developments of water demand and reservoir storage. The IMPREX approach is especially helpful for dry years, when effective and efficient drought management is indispensable. AQUATOOL's skilled meteorological forecasts and improved schemes to link forecasts to local hydrological conditions have been used successfully to reduce uncertainties of decision-making.
IMPREX shows that improved accurate forecasts over a range of time scales are in high demand within the Mediterranean. That is why AQUATOOL can be an essential tool to improve effective drought management.

> *The work done within IMPREX has significantly improved the results of estimating drought risks - Javier Macian, Aguas de Valencia*

For further information please visit www.imprex.eu and check out our interactive product demonstrator!

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IMPREX is designed to help reduce Europe's vulnerability to hydrological extremes by achieving a better understanding of the intensity and frequency of potential disrupting events. Enhancing our forecasting capability will increase the resilience of European society as a whole, while reducing costs for strategic sectors and regions at the same time. The research project brings together 23 partners from 9 countries and has received funding from the European Union's Horizon 2020.