

D.5.4: Documentation of selected drought monitoring models and workflows

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ACRONYMS AND ABBREVIATIONS

Abbreviation	Name
AIP-2	Architecture Implementation Pilot, Phase 2
AOC	Advanced Operating Capacity
CHE	Confederación Hidrográfica del Ebro, Spain
CNIG	Centro Nacional de Información Geográfica, Spain
CSIC	Consejo Superior de Investigaciones Científicas
CSW	Web Catalogue Service
DMCSEE	Drought Management Centre for Southeastern Europe
DoW	Description of Work
DOPA	Digital Observatory of Protected Areas
EC-JRC	European Commission, Joint Research Centre
EDO	European Drought Observatory
FGDC	Federal Geographic Data Committee
FGUA-OSE	Fundación General de la Universidad de Alcalá, Observatorio de la Sostenibilidad en España
IDE	Infraestructura de Datos Espaciales (Spatial Data Infrastructure)
IDEE	Infraestructura de Datos Espaciales de España (National Spanish Spatial Data Infrastructure) Spatial Data Infrastructure of Spain
IOC	Initial Operating Capacity
MARM	Ministerio de Medio Ambiente y Medio Rural y Marino (Ministry of Environment, Rural and Marine Affairs), Spain
ONS	Observatorio Nacional de Sequía (National Drought Observatory), Spain
OWS	OGC Web Services
RDF	Resource description framework
SAIH	Sistema Automático de Información Hidrológica (Automated hydrology information system for Spain)

SBA	Societal Benefit Area
SEE	Southeastern Europe
SIA	Sistema de Información del Agua (Water Information System), Spain
SKOS	Simple Knowledge Organization System
SLD	Styled Layer Descriptor
ULBF	Univerza v Ljubljani
UMN	University of Minnesota
UNEP	United Nations Environment Programme.
UNIZAR	Universidad de Zaragoza
WCMC	World Conservation Monitoring Centre
WCS	Web Coverage Service
WCTS	Web Coordinate Transformation Service
WFS	Web Feature Service
WMC	Web Map Context
WMS	Web Map Service
WP	Work Package

1 INTRODUCTION

The basis of the EuroGEOSS project is a web service infrastructure for the discovery and access to data from various thematic areas. The ultimate goal of the project is to explore possibilities to automatically derive information from observations and raw data and also to combine data coming from different disciplines to generate new insights. These tasks require the characterization of workflows followed in scientific modeling tasks or decision processes.

The workflows can mix human tasks, e.g. expert decision from exploring a map representing a particular indicator, and technically supported tasks such as computing this indicator in the first place. The descriptions of workflows (see also EuroGEOSS D 2.3.1) help the modeler to refine and publish the scientific model and the user to replicate accurately the model and have a standardized presentation of the scientific model. Later on, this standardized presentation can potentially be used for implementation purposes using for example web processing services for parts that can be automatized.

The drought group works on making drought related data for drought monitoring retrievable and usable. For these purposes the EuroGEOSS initial operating capacity (IOC) has been set up. Added research capabilities following from the IOC are explored towards an advanced operating capacity (AOC); the implementation of an AOC is not targeted for the drought group, which means that the implementation of workflows is not required.

The present document provides formal descriptions of some workflows that are part of the IOC and others that could become part of the AOC. At present, drought experts face three main tasks involving models or workflows:

- the discovery of drought related data,
- the production of drought indices from raw data and
- the validation of drought indices in different terms.

The discovery of drought related data is based on the drought IOC and the interaction of the European drought observatory with the drought metadata catalogue. The metadata catalogue was extended with a drought specific vocabulary, which is presented in section 2; the discovery procedure itself is discussed in section 3. When drought experts have raw data available, they run through a sequence of steps for assessing the quality of the data and deriving drought indices. This workflow is introduced in section 4.

Another aspect of drought research is the validation of drought indices. Drought index validation involves a series of tasks that are related to workflows in the drought IOC and to research questions of the drought WP. Parts of the analysis for comparing drought indices with different spatial resolution are shown in section 5. Summary and conclusions are given in section 6.

2 THE EUROGEOSS DROUGHT VOCABULARY – A SPECIALIZED THESAURUS

Metadata are one important component of the drought IOC. The team from University of Zaragoza set up a metadata catalogue for searching metadata on drought related data and services. The search for metadata can be done with different parameters: provider, date, free keywords and keywords from existing thesauri. The thesauri used in the EuroGEOSS project are:

- GEOSS Societal Benefit Areas (SBA), including categories, and subcategories¹,
- GEMET (General Multilingual Environmental Thesaurus),
- INSPIRE topic category codes,
- INSPIRE spatial theme keywords.

The keywords coming from existing thesauri (SBA, GEMET, INSPIRE) turned out to be highly general. In the SBA subcategories, for example, only the term 'drought prediction' can be found under the category of water. Under the 'disasters' category the keyword 'extreme weather' can be found that may or may not be related to drought. In GEMET the keyword 'drought' can be found as part of meteorological phenomena on the fourth sublevel of the thesaurus. INSPIRE topic category codes offer 'climatologyMeteorologyAtmosphere' as category related to droughts.

The drought WP decided that these existing keywords do not offer the desired level of detail for drought experts to search for specific datasets related to droughts. In addition, the use of these thesauri may not be intuitive for users of the catalogue since the drought related terms are hidden in subsections of the thesauri. This experience was the reason to prepare a list of drought related keywords that describe the data and services of the partners.

We decided to group drought-related keywords in topic categories and define links between these categories. The resulting graph of this grouping is displayed in ANNEX B. This grouping of terms in categories has been translated to the SKOS representation of the drought thesaurus in terms of SKOS collections. SKOS is the Simple Knowledge Organization System as defined by the semantic web activity of the world wide web consortium <http://www.w3.org/2004/02/skos/>. SKOS vocabularies are serialized in XML format. This format is already used for GEMET, SBA, etc. and can be included in the search requests on metadata.

The following example shows how the links between 'agricultural drought' and related terms is represented in the SKOS representation (Figure 1). The description of the term agricultural drought provides a URI for the unique identification of this term. The related terms have URIs ending on 61 and 87, the URI ending on 15 links agricultural drought to a broader term. Looking through the SKOS representation of the vocabulary tells us that the concept identified with number 61 is 'meteorology'; 87 refers to 'soil moisture' and the broader term linked to agricultural drought is 'drought' (URI number 15). This corresponds of course to the graphical representation of the drought vocabulary in ANNEX B.

The SKOS representation shown in Figure 1 indicates also the available translations of the drought vocabulary. The terms are available in Bosnian, English, French, German, Spanish, Slovenian, Turkish, Albanian, Serbian, Italian, Croatian, Macedonian, Greek, Montenegrin, and Portuguese.

The initiative to come up with a drought vocabulary in WP5 led to a specialized thesaurus that defines concepts and relations in the drought monitoring domain. The presentation of the drought vocabulary in the interface of the metadata catalogue is done as an alphabetically ordered list with subgroups that contain the alternative terms. The drought catalogue searches for the specified keyword in the title, abstract, and keywords of the metadata descriptions (Figure 2). Additional terms from the more general thesauri (SBA, GEMET, INSPIRE topic categories etc.) can be added to the search restrictions too (Figure 3).

The quality of results of queries posed in the metadata catalogue depends on the quality of the metadata descriptions. WP5 is currently updating the metadata to include a series of keywords

¹ http://en.wikipedia.org/wiki/Societal_Benefit_Areas

from the drought vocabulary in the descriptions of data and services. For this purpose, the metadata editor tool of the University of Zaragoza, CatMDEdit, can be extended with the drought vocabulary. All required information can be found on <http://eurogeoss.unizar.es/home/>.

```

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  xmlns:skos="http://www.w3.org/2004/02/skos/core#">
  ...
  <rdf:Description rdf:about="http://eurogeoss.eu/DroughtVocabulary/104">
    <skos:related
  rdf:resource="http://eurogeoss.eu/DroughtVocabulary/61"/>
    <skos:related
  rdf:resource="http://eurogeoss.eu/DroughtVocabulary/87"/>
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    <skos:inScheme
  rdf:resource="http://eurogeoss.eu/DroughtVocabulary"/>
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    <skos:prefLabel xml:lang="sl">hidrološka suša</skos:prefLabel>
    <skos:prefLabel xml:lang="fr">sécheresse agricole</skos:prefLabel>
    <skos:prefLabel xml:lang="es">sequía agrícola</skos:prefLabel>
    <skos:prefLabel xml:lang="de">Landwirtschaftliche
  Dürre</skos:prefLabel>
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  </rdf:Description>
  ...
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    <rdf:type
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    ...
  </rdf:Description>
  ...
  <rdf:Description rdf:about="http://eurogeoss.eu/DroughtVocabulary/87">
    <skos:prefLabel xml:lang="en">soil moisture</skos:prefLabel>
    <rdf:type
  rdf:resource="http://www.w3.org/2004/02/skos/core#Concept"/>

```

Figure 1: Extract from the SKOS representation of the drought vocabulary



Figure 2: Using the drought vocabulary for searching the metadata catalogue

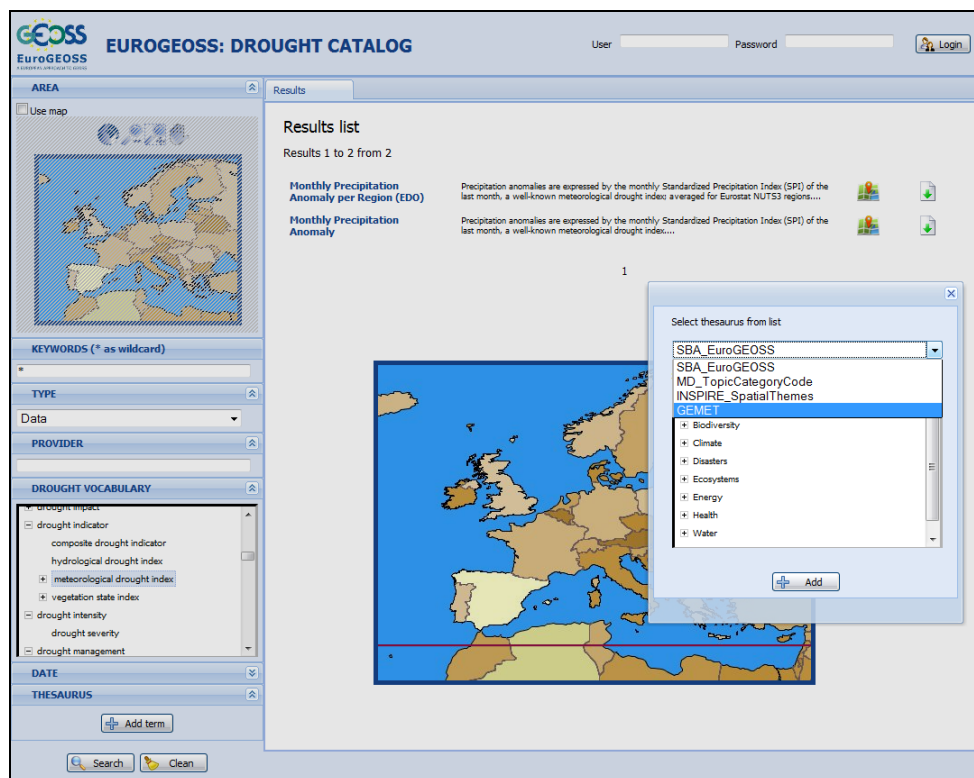


Figure 3: Including terms from additional thesauri in the search interface

3 DISCOVERY OF DROUGHT RELATED DATA WITH THE DROUGHT INITIAL OPERATING CAPACITY

The objectives of the drought IOC and the ways of using it are discussed in the user requirements document, which has recently been provided in a revised version [EuroGEOSS, 2011a]. The first generation of use cases covered general aspects of the drought IOC with a focus on discovering and displaying drought related data. The IOC was developed according to these scenarios. The extensions of the IOC functionality aim at improving existing procedures of using the IOC: the metadata are refined for suiting the needs of drought experts, the search in the metadata catalogue has been improved, and the web map services (WMS) will be available in English, French and Spanish through a connector tool. A new feature that is added to complement the IOC is the download of data through the employment of web coverage services (WCS).

Figure 4 describes some general steps of the interaction between the user, the EDO map viewer and the metadata catalogue in Business Process Modeling Notation (BPMN); the steps are explained in Table 1. The focus is on the selection of data of interest and the visualization of these data with the help of WMS in the EDO map viewer. If the data are also available for download, the user can use the interface of the web coverage service for retrieving the data of interest.

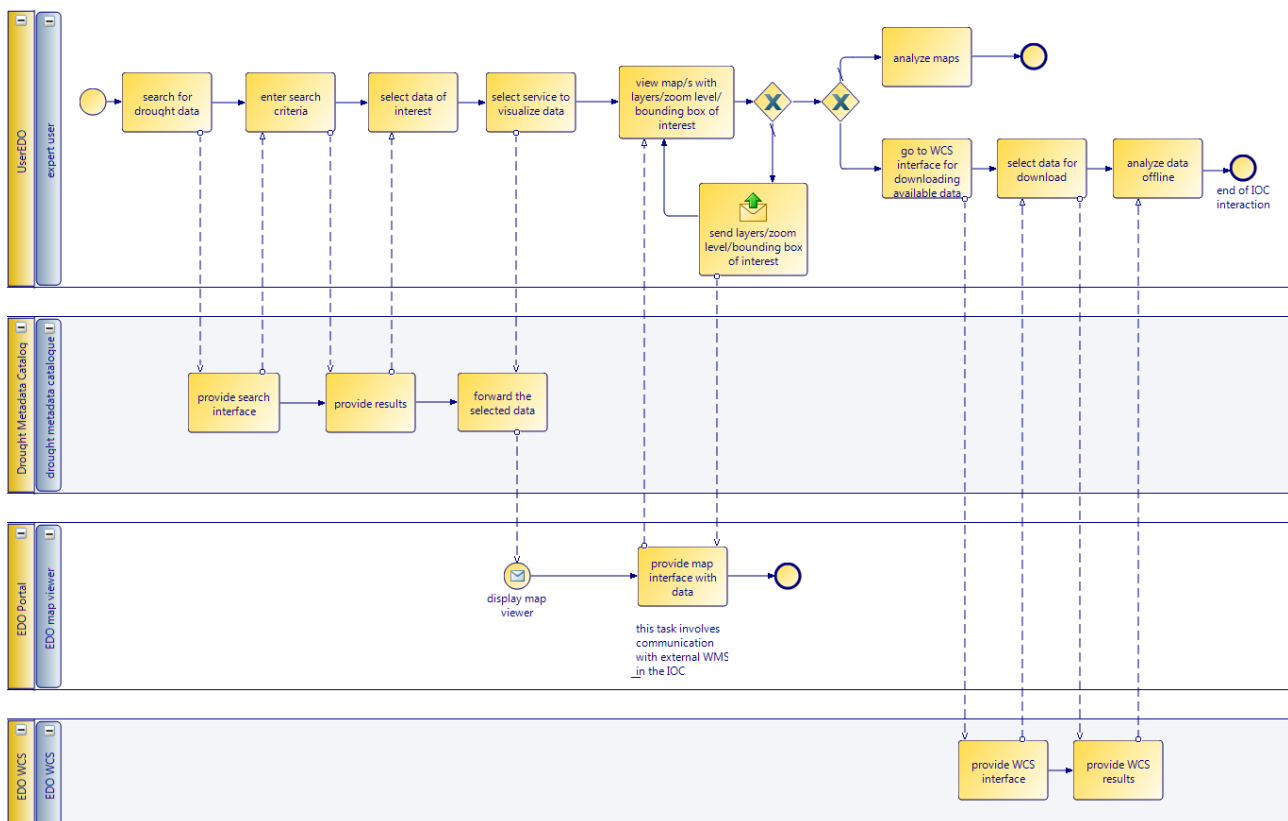


Figure 4: Workflow visualization of the interaction between a user, the EDO map viewer and the metadata catalogue.

Step/Task	Description
Search for drought data	The user would like to discover drought related data and goes to the metadata catalogue.
Provide search interface	The metadata catalogue is displayed and offers an interface for specifying the search.
Enter search criteria	The user enters search criteria.
Provide results	The search in the catalogue is performed and results are displayed.
Select data of interest	The user goes through the results and checks which data are of interest for him.
Select service to visualize data	The data can be accessible as WMS or WFS, which can either be stated in the online resource field or which can be found in the service section of the catalogue.
Forward the selected data	The drought metadata catalogue forwards the request of a service to the EDO mapviewer
Provide map interface with data	The request for data from a WMS is processed within the EDO map viewer and the service displayed.
View map/s with layer/s, zoom level, bounding box of interest	Use of the EDO map viewer for exploring the data.
Send layers/zoom level/bounding box of interest	The user can explore the map and use the functions of the mapviewer until the maps correspond to his needs; then he moves on to the next steps of map analysis and download of data.
Analyze maps	The user can get an overview of the drought index maps and derive his interpretation of the situation.
Go to WCS interface for downloading the data	In case online analysis of the maps is not sufficient, the user wants to download the drought data and accesses the WCS interface for retrieving raster data.
Provide WCS interface	The server provides an interface with the available layers for download.
Select data for download	The user specifies the layers he would like to retrieve as well as spatial and temporal extent and additional properties.
Provide WCS results	The WCS server processes the request and provides the user with the data – potentially in a data package.
Analyze data offline	The user may now open the data in his preferred software tool and start his analysis.

Table 1: Description of the steps of the interaction scenario from Figure 4

4 INDEX GENERATION PERFORMED BY A DROUGHT EXPERT

A drought index provides quantitative information for monitoring drought conditions. A range of indices are available that provide measures of drought at various stages of the water cycle from the meteorological rainfall input through to soil moisture availability, hydrological groundwater availability and indices related to vegetation greenness. The examples of drought indices used later in this section are [EuroGEOSS, 2011b]:

- The standard precipitation index (SPI) that provides a measure of anomalies in precipitation over time periods of one, three, six or twelve months (McKee et al., 1993).

- The standard precipitation-evapotranspiration index (SPEI) that takes into account potential evapotranspiration and precipitation (Vicente-Serrano et al., 2010).
- The standardized streamflow drought index (SSI) that is a hydrological index providing information on duration, magnitude and intensity of hydrological droughts (Vicente-Serrano et al., 2011).

This section discusses the task of producing drought indices by means of an exemplary workflow. The workflow description highlights the importance of the direct involvement of drought experts in these tasks. At the moment, the automatization of index generation by, e.g., web processing services, is not envisaged in the drought workpackage.

The preparation of a drought index starts with the choice of a specific index. This choice depends on factors such as data availability, regional characteristics, and the planned use of the index in decision making. The discussion of drought indices, methods to produce them, validation results, etc. takes place in the research community and scientific literature regarding drought.

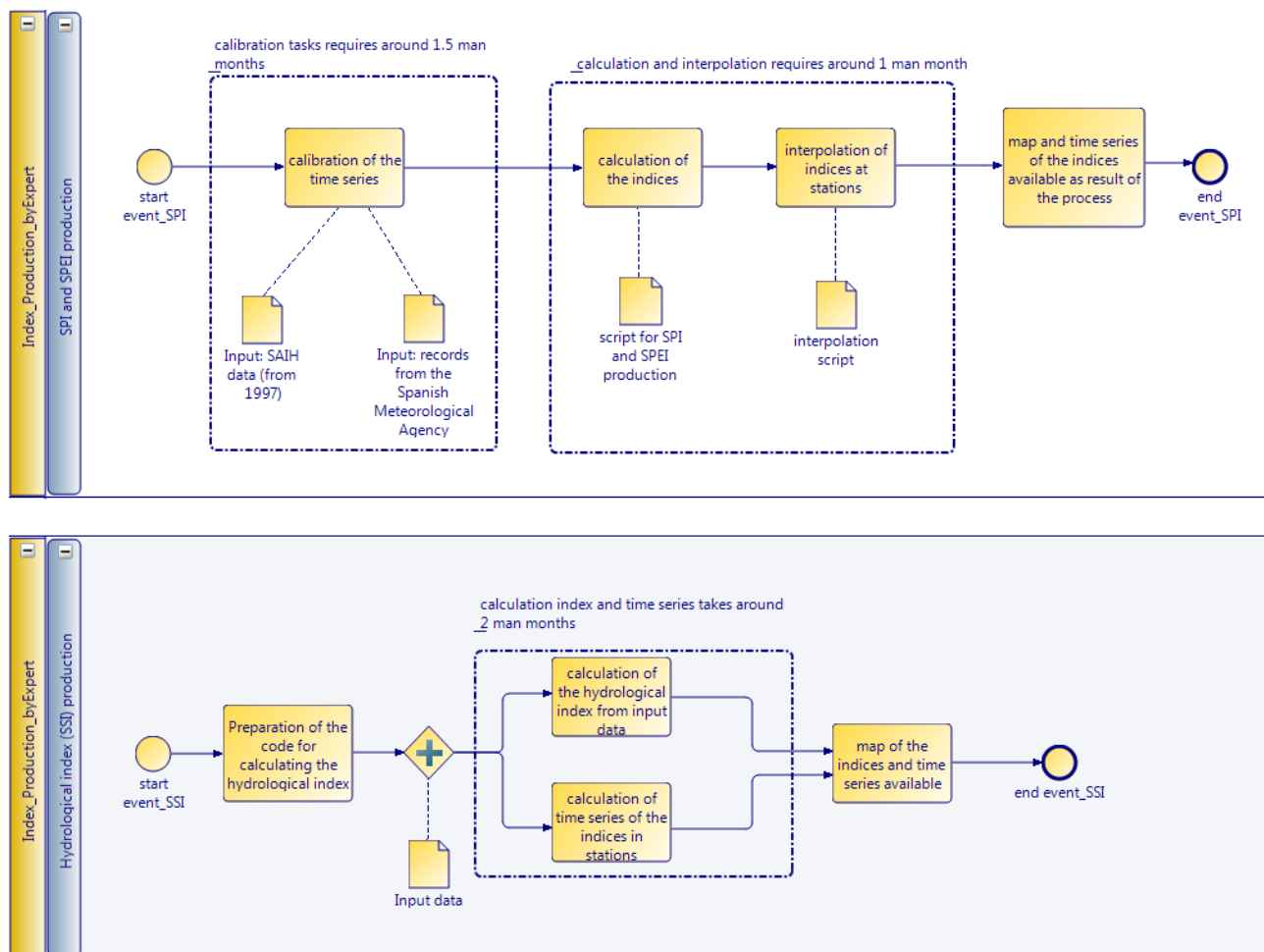


Figure 5: Workflows and estimated expenditure of time for drought index generation

Step/Task	Description
Calibration of the time series	Quality control and adaptation of the input data.
Script for SPI and SPEI production	Programming of the computer code containing the procedure to calculate SPI and SPEI indices.
Calculation of the indices	With a script for SPI and SPEI calculation the indices can be calculated based on the previously calibrated input data.
Interpolation script	Programming of the computer code containing the commands for data interpolation.
Interpolation of the indices	The calculated indices are interpolated at the stations to derive information not only at stations but in all the study area.
Map and time series of the indices	As a result of the procedure, maps and time series data of the indices are available.
Preparation of the code for calculating the hydrological index	Programming of the computer code containing the commands for calculating the hydrological SSI index.
Calculation of the hydrological index	Application of the computer code for calculating the hydrological index from the input data.
Calculation of time series of the indices	Application of the computer code for deriving the time series of the SSI index from the input data.
Map and time series of the index	As a result of the procedure maps and time series of the SSI hydrological index are available.

Table 2: Description of the steps of the drought index production procedure of Figure 5

The project partner CSIC provided an overview of the workflow involved in the production of SPI, SPEI, and SSI for the Ebro river authority (Figure 5, Table 2). An important part is the calibration of climate time series (precipitation and temperature) for the SPI and SPEI, which would require an effort of 1.5 man-months. The calibration involves the reconstruction, quality control and homogenisation of the climate time series to obtain reliable drought indicators.

The tasks of series calibration, calculation of the indices, interpolation and mapping require substantial expertise with different input data, statistical methods, mapping tools, etc. on the side of the drought expert. The total effort for producing a drought index was indicated by approximately three man months. In addition, contacts to data organizations and access rights for input data are required for starting the production of drought indices. The production of drought indices requires the adaptation of general scientific methods to each specific case; every model for drought index generation differs due to varying initial situations, regional variations, data availability, etc.

In the EuroGEOSS project we rely on the knowledge of local experts for producing drought indices suiting their data availabilities and interests. Therefore, the focus of the drought IOC is on sharing drought index data rather than base data.

5 WORKFLOW DESCRIPTION OF AN EXEMPLARY RESEARCH QUESTION

The drought WP set up an initial operating capacity in the first half of the project lifetime. The second half of the project is dedicated to identifying the research capabilities added by the IOC as well as validating and testing the interoperable infrastructure. A series of research questions of

interest in the drought community are listed in ANNEX A. More specifically, CSIC and DMCSEE are working on three research questions:

- Comparison between drought indices obtained from various climatic datasets at varied spatial scales (from high resolution nets of meteorological stations to low resolution continental and global gridded datasets),
- Impact of climatic drought on hydrological droughts in the Ebro basin: capability of the climate drought indices to monitor hydrological droughts and to understand how the climatic droughts propagate throughout the hydrological cycle,
- Assessment of the capability of different drought indices to monitor agricultural impacts in Slovenia.

These research questions will serve as a test of added research capabilities that will be further explored in task 5.6. The results and insights gained in the research activities will be shown in a report for task 5.7.

The specific research task that is presented in a BPMN diagram is the comparison of different drought indices. These drought indices are obtained from various climatic datasets at varied spatial scales in the Ebro basin (Spain) and Slovenia. The leading idea is to find out, if drought periods are correctly identified in datasets with a lower spatial resolution or if drought monitoring needs to be based on indices calculated from detailed local data. The focus is on the Standardized Precipitation Index (SPI) with a time resolution of three, six, nine and twelve months since this index requires only precipitation records as input.

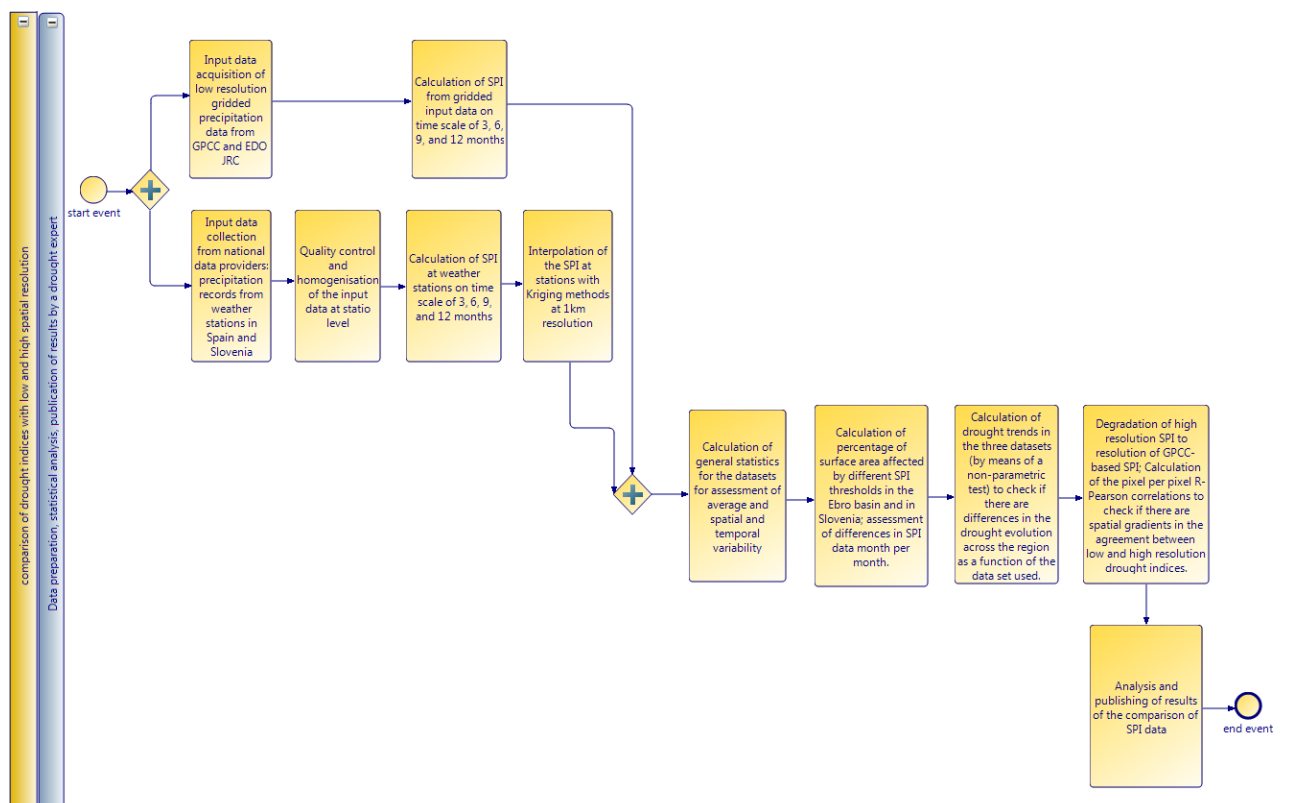


Figure 6: Comparison of drought indices based on a statistical assessment

Step/Task	Description
Input data acquisition of low resolution gridded precipitation data from GPCC and EDO JRC.	GPCC, the global precipitation climatology center, provides low resolution gridded precipitation data, and the JRC provides continental precipitation data with low resolution as well.
Calculation of the SPI from gridded input data on time scale of 3, 6, 9, and 12 months.	The computer code to calculate the SPI is applied with these input data.
Input data collection from national data providers: precipitation records from weather stations in Spain and Slovenia.	National data providers contribute high resolution precipitation data at weather stations for Spain and Slovenia.
Quality control and homogenization of the input data at station level.	The experts have to check the quality of the received data, reconstruct and homogenize the precipitation data from the stations.
Calculation of SPI at weather stations on time scales 3, 6, 9, and 12 months.	If the data are checked the SPI for different time scales can be computed at the weather stations; the computer program is the same that is used with the gridded input data.
Interpolation of the SPI at weather stations with Kriging methods at 1km resolution	The SPI data calculated for the weather stations need to be interpolated to have information for all points in space.
Calculation of general statistics for the dataset for assessment of average and temporal and spatial variability.	General statistics give first insight in the SPI from the different sources.
Calculation of percentage of surface area affected by different SPI thresholds in the Ebro basin and in Slovenia. Assessment of differences in SPI data month per month.	After selecting a certain SPI value as threshold, the percentage of the area having this value can be calculated for every dataset. The comparison of the affected surface area gives an insight in the correspondence of the drought information provided by the data. This calculation is repeated for every month for the two study areas in Spain and Slovenia.
Calculation of drought trends in the three datasets (by means of a non-parametric test) to check if there are differences in the drought evolution across the region as a function of the data set used.	Drought trends as represented in the three data sets are compared to assess the differences in the data sets over time.
Degradation of high resolution SPI to resolution of GPCC-based SPI; Calculation of the pixel per pixel R-Pearson correlations to check if there are spatial gradients in the agreement between low and high resolution drought indices.	The high resolution data are degraded for the lowest available resolution to apply statistics that show the spatial distribution of the SPI values.
Analysis and publishing of results of the comparison of SPI data.	The insights gained through the comparison of the three data sets are analyzed, interpreted, and published as a result of this research task.

Table 3: Description of the steps involved in the research scenario of Figure 6

The diagram in Figure 6 shows the steps required for a quantitative evaluation of the capability of drought indices calculated at different spatial resolutions for assessing the evolution and severity of climate drought in a given region. Table 3 contains explanations of the single steps.

Further research will be conducted to compare the effectiveness of the different drought indices applied to two key economic sectors: water resources and agriculture. Since the main purpose of the drought monitoring and early warning systems is to assess real drought impacts on society, economy and the environment, the methodology proposed allows making an objective quantification of the real usefulness of the different SPI datasets for this purpose.

6 SUMMARY AND CONCLUSIONS

This report summarized formal workflow descriptions available in the drought workpackage. The available descriptions comprise the drought vocabulary, the interaction of a user with the drought initial operating capacity, the steps of drought index production, and a workflow involved in a research task. The documentation indicates the focus of the drought WP on workflows related to the drought IOC and research activities.

The drought work package does not work on the automatizing of the presented workflows or web processing services at the moment. Drought indices are, however, used by the thematic areas of Forest and Biodiversity in their analysis. A first observation of the interaction with these thematic areas shows that additional data preparation of the drought team is required for satisfying the needs of other thematic areas.

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ANNEX A – DROUGHT RESEARCH QUESTIONS

Topic	Spatial domain and scale	Potential partners	Relation to EuroGEOSS	Timeframe
Inter-comparison of (a) selected drought index (indices) such as SPI, derived e.g. from gridded continental-scale, representative national or station data, and high-density regional network data	Spain; regional, national, continental	CHE, OSE/SIA, JRC, CSIC, BRGM-Water	Supported by EuroGEOSS approach; within scope; within timeframe;	By 2011
Improving the dissemination of drought information, benefitting from DMSEE and EDO experience and existing IDE Ebro	Ebro catchment area; regional	CHE, JRC, ULBF	Not core objective of EuroGEOSS, but partly supported through EuroGEOSS; achievable within timeframe	By 2011
Analyse various methods for drought forecasting from medium-range to monthly meteorological ensemble forecasts as well as seasonal prediction by statistical relationships with large-scale circulation patterns (e.g. NAO, classification of "Wetterlagen")	All Europe; continental to regional	EDO, CSIC, ULBF, CHE	Outside scope and timeframe	Long-time perspective of years
Case study on selected drought event(s) for inter-comparison of different drought indices derived from datasets of different spatial resolution, including impact information on vegetation, agriculture	Ebro catchment area; regional	EDO, CSIC, CHE, OSE/SIA, BRGM-Water, CNIG	Supported by EuroGEOSS approach; within scope; requires R&D resources probably beyond EuroGEOSS; achievable within timeframe	within few years
Identification of common drought indices for all scales and hydrological systems as starting point for multi-scale comparison	All Europe; continental to regional	OSE/SIA, CSIC, EDO, ULBF, BRGM-Water	Supported by EuroGEOSS approach; within scope; within timeframe	By 2011

Topic	Spatial domain and scale	Potential partners	Relation to EuroGEOSS	Timeframe
Application of drought information for improved assessment of sustainability (tb specified); derivation and application of drought hazard and risk maps as input to sustainability analysis	Spain; National	OSE/SIA, EDO, CHE, CNIG	Supported by EuroGEOSS approach; marginal to scope; achievable within timeframe; might require additional R&D resources	Within few years
Use of drought impact information within drought indicators, with special focus on economic impacts	Predominantly regional	CHE, EDO, CSIC	Outside scope and approach; requires additional R&D resources	Within (few) years
Inter-comparison of different drought indices between national, international, and continental scale; evaluation of international/sub-continental focal point and respective information	SE Europe, national to continental	ULBF, EDO, BRGM-Water	Supported by EuroGEOSS approach, within scope; first results achievable within timeframe, to be continued for all DMCSEE MS	First results by 2011, to be continued

Table: drought research questions identified in the 1st EuroGEOSS WP5 Meeting, Zaragoza, 23./24. June 2009

ANNEX B – CONCEPTS AND RELATIONS OF THE DROUGHT VOCABULARY

This annex shows an schema of the concepts and relations defined within the drought vocabulary in a graphical way. In this schema the concepts are represented by their label in English. However, there are also alternate labels (synonyms) and translations to the other fourteen languages available. The blue boxes are used to identify groups of concepts, which are closely theme-related.

With respect to relations, this schema shows the following relations among concepts: *is-a* to identify inheritance between concepts (e.g., a “rainfall anomaly” is a kind of “precipitation anomaly”); *whole-part* to identify composite relations between concepts (e.g., “drought duration” has an “onset” and an “end”); *instance-of* to identify the instances of a concept (“EDO” is an instance/individual/particular case of a “drought monitoring system”); and *related* to identify lighter associations between concepts without a hierarchical meaning (“soil” is related to “soil moisture”).

As regards the serialization of these relations to SKOS, it must be noted that *is-a*, *whole-part* and *instance-of* relationships are mapped to *skos:broader* and *skos:narrower* relations. The related relations are mapped to an equivalent SKOS relation: *skos:related*.

This schema and its representation in SKOS format can be downloaded from <http://eurogeoss.unizar.es/home/>.

Notation:

- ▷ is-a
- ◆— whole-part
- - -▷ instance of
- related

